SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

The JOURNAL of the FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Special Features

Determination of Storm Overflows from Intercepting Sewers—Hess and Manning

Pollutional Effects of Combined Sewer Overflows—Palmer

Phenols Determination—Riehl and Will

Anti-Biotics Waste Treatment—Hilgart

FEBRUARY, 1950—VOL. 22, No. 2

Make Plans to Attend—

TWENTY-THIRD ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

IN CONJUNCTION WITH

MARYLAND-DELAWARE WATER AND SEWERAGE ASSOCIATION (SEWAGE WORKS SECTION)

AND

FEDERAL SEWAGE RESEARCH ASSOCIATION

STATLER HOTEL

WASHINGTON, D. C.

October 9-12, 1950

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

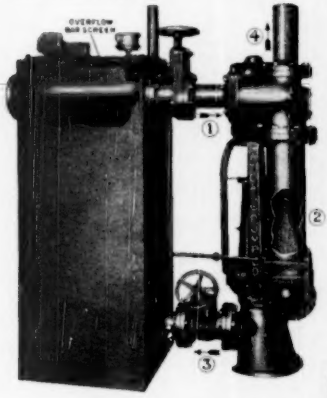
CHICAGO" PUMPS

FOR SEWAGE AND SLUDGE

FLUSH KLEEN EJECTORS FOR SEWAGE

"Flush Kleen" pumps provide automatic, trouble-free service in sewage lift-stations. They require no manual attention except periodic lubrication and inspection. No labor is required for disassembling and cleaning clogged pumps as with other types.

The impellers handle only strained sewage. No solids pass through the impeller to cause excessive strain and wear on impeller, shaft, bearings or motor; pumps remain in balance and operate economically with little attention.

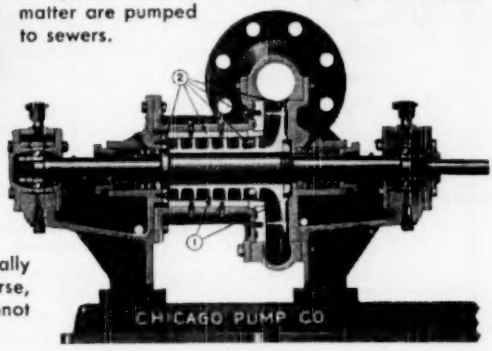


Filling Wet Well

1. Sewage flows through inlet pipe.
2. Coarse matter is retained on strainer.
3. Strained sewage flows through idle pump to wet well.

Pumping

3. Strained sewage is pumped from wet well.
2. Coarse matter is backwashed from strainer.
4. Special check valve closes; sewage and coarse matter are pumped to sewers.



SCRU-PELLER PUMPS FOR SLUDGE

The Scru-Peller Pump was specifically designed to handle sludge. Coarse, stringy material is cut and cannot wrap or bind the impellers.

1 SCREW and IMPELLER are keyed on the shaft and held firmly against a shoulder on the shaft by a nut. The screw has two flights; and the impeller has two blades. Each flight in the conveyor connects directly with its own blade of the impeller.

2 CUTTING EDGES. There are four cutting bars and a cutting ring in the screw housing and four cutting bars in the pump casing. The cutting takes place between the edges of the screw and the cutting edges in the screw housing, between the edges of the impeller blades and the cutting edges in front of the impeller, and between the edges of the impeller blades on the back of the impeller and the cutting edges of the pump casing.

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SEWAGE EQUIPMENT DIVISION

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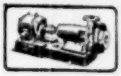

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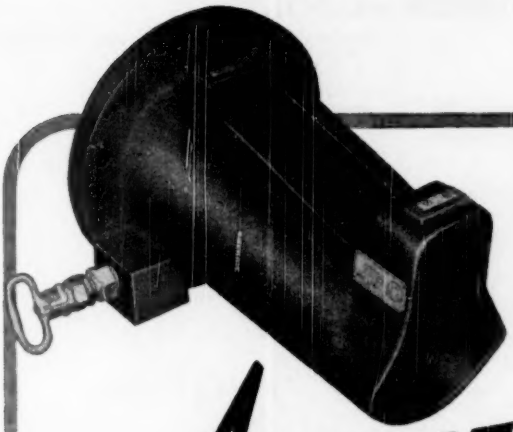

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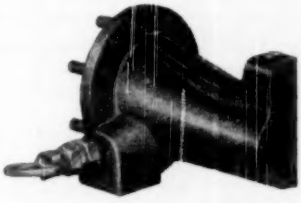

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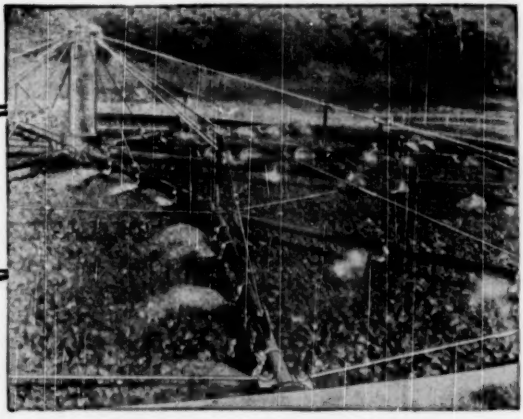

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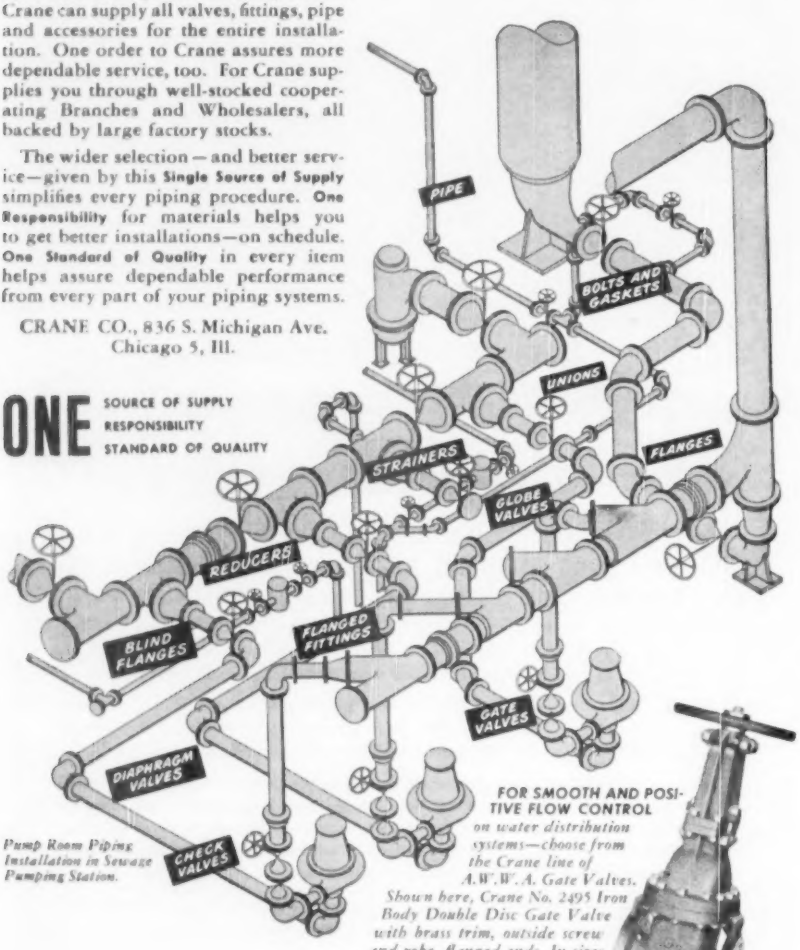

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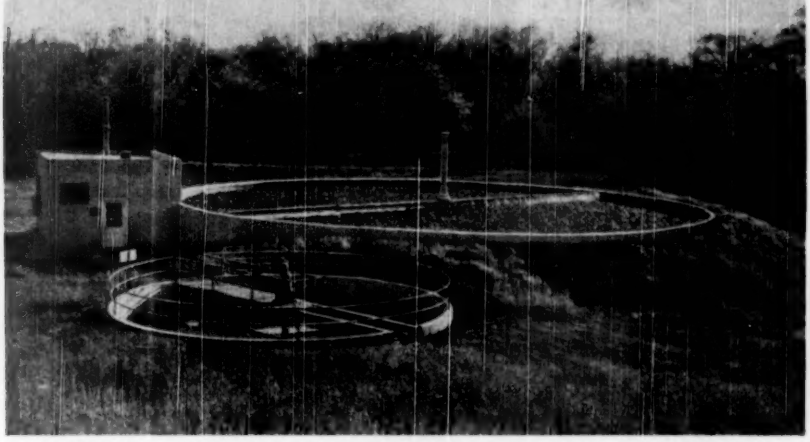
A BETTER SYSTEM OF DIRECT RECIRCULATION FOR SEWAGE PLANT OPERATION



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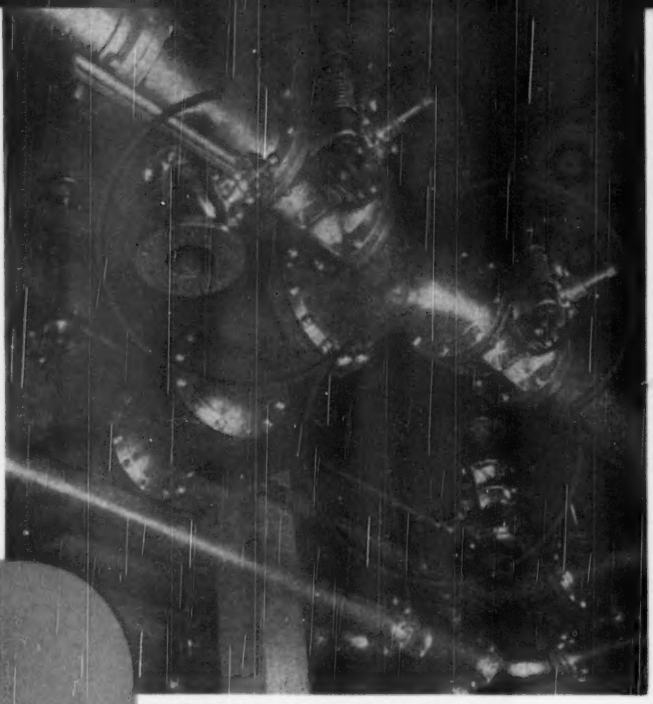
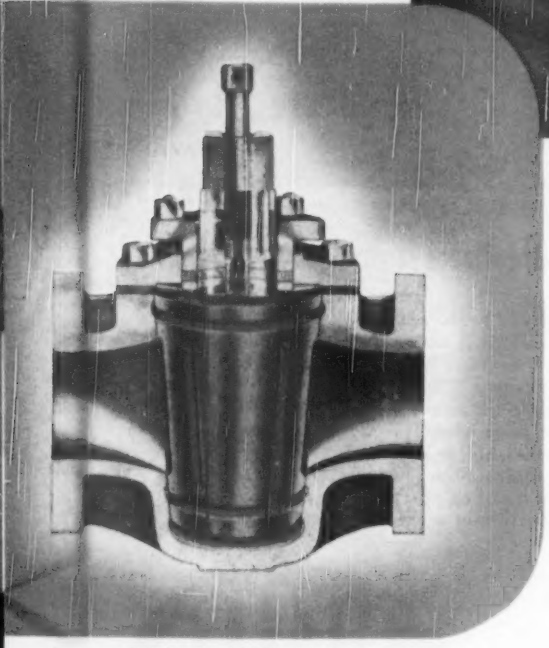
- Quarter-turn, easiest operation



Nordstrom valves on sludge feeders in vacuum filter room



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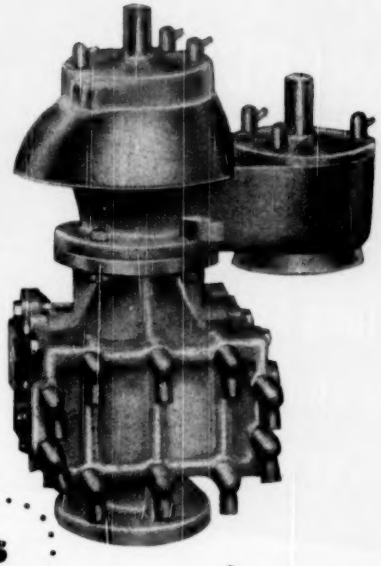

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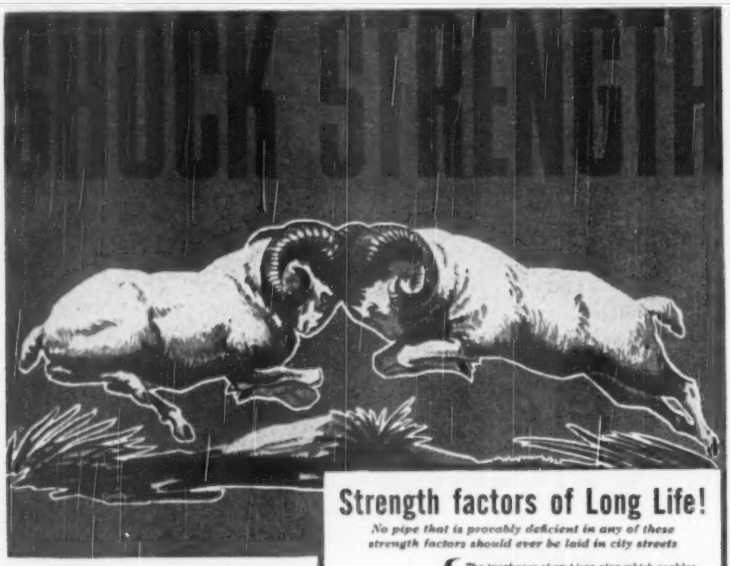

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The Journal of the Federation of Sewage Works Associations

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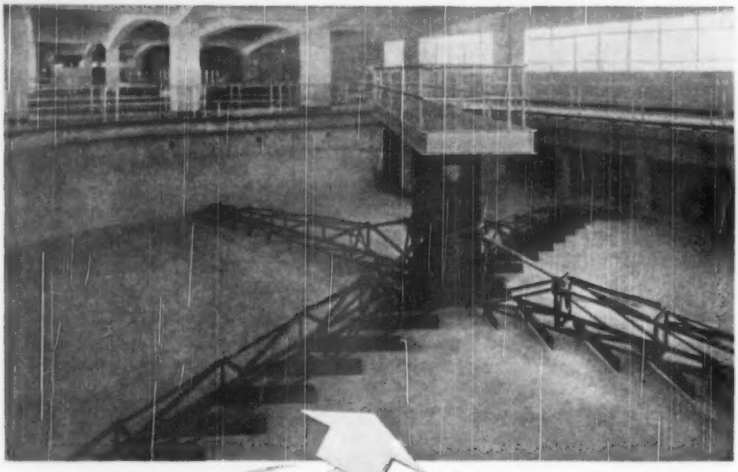

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Sewage Works

A RATIONAL DETERMINATION OF STORM OVERFLOWS FROM INTERCEPTING SEWERS *

By Seth G. Hess and Frank G. Manning

Director and Chief Engineer, and Principal Sanitary Engineer, respectively, Interstate Sanitation Commission, New York, N. Y.

Interceptors for combined sewer systems are expected to have capacity for the dry-weather flow plus an amount of surface runoff. To design these interceptors on the basis of a percentage of the dry-weather flow is not rational. Accordingly, it is proposed that these designs be based on dry-weather flow plus the runoff of a selected storm, the storm selected to depend on conditions developed herein. In its present form, this study is the limited development of a rational basis for the design of intercepting sewers. The study is set forth in this stage of development for two reasons—to invite critical comment and to encourage additional exploration by other agencies and individuals.

In this approach the rational formula, generally employed in the design of storm drains, is incorporated in the design of interceptors for combined sewers. Sample curves have been developed to illustrate the facility with which the method may be applied. Several designs of sewers in the New York metropolitan area have been compared on the basis of these tentative curves. Although the curves are tentative, the differences in volume of overflow that obtain from such current practices are significant and would seem to justify furtherance of the study. It appears to offer one means of designing intercepting sewers with a knowledge of the probable quantity or frequency of overflow of combined sewage to be expected.

The Problem

In general, pollution in the vicinity of the point of overflow of combined sewage is recognized as being influenced by many factors. Principal among these are the present or intended use of the receiving waters, their characteristics, the dilution provided, the quantity and strength of the diverted sewage, the frequency and season of the overflow, and the degree of treatment provided at the sewage treatment plant. It must also be recognized that the use of the receiving waters may dictate that control of bacterial pollution should take precedence over any chemical or biochemical consideration.

Normally, a combined sewer system has been constructed to accommodate many times the dry weather flow. Under such circumstance, in planning the interceptors it is not found feasible to intercept the total flow from each terminal of the combined sewer system for conveyance to a point of ultimate disposal or treatment. The specific

* Presented at Metropolitan Section Meeting, New York State Sewage Works Association; New York, N. Y.; June, 1949.

problem is the evaluation of how much of this storm sewage can be by-passed and, accordingly, how much storm flow must be intercepted. The solution may have economic as well as health significance. The amount and frequency of storm sewage overflow is a matter of concern both to the designing engineer and to the agencies charged with the control of pollution and the protection of the public health.

Past Practice

In the design of intercepting sewers, provision is usually made for the dry weather flow with or without some increased allowance for surface runoff. Such added allowance has usually been provided for in the form of a multiple of the dry weather flow. An example is the City of New York, where the use of a factor of the dry weather flow in the design of interceptors has been intrinsic to the practice from the very beginning. The Metropolitan Sewerage Commission (1914) reported the conclusion of their consultants that interceptors for New York City should provide capacity for twice the average dry weather design flow, it being estimated that the maximum dry weather flow would be 150 per cent of the average flow. It was felt that such allowances would assure the conveyance, after rainfall, of a large part of the first flush of street washings to the treatment plants. Rudolf Hering, one of the consultants, advised that the first flush from the streets "is sometimes as foul and as dangerous as ordinary sewage" and should be allowed to mingle with domestic sewage for equal treatment.

Concern over pollution at the point of overflow is not limited to the so-called "first flush" of street washings. To begin with, pollution from animal and other wastes washed from the street surfaces has been reduced considerably and, in many places, street cleaning and flushing are routinely accomplished. Secondly, the first flush of storm sewage will carry with it organic sediment previously stranded in the sewers as well as any street-surface pollution flushed to the sewer. Thirdly, this first flush must be recognized as being more than an instantaneous condition. It seems reasonable to expect that street flushing will continue to be discharged to or beyond the time of maximum concentration, and organic sediment will continue in the overflow until the scouring velocity has been sufficiently prolonged to complete the scouring action throughout the collecting system. The flushing action caused by rainfall may not always be the matter of primary concern. It is conceivable that circumstances may direct consideration to the pollution emanating from overflows or regulators at any time in the course of, or after, a storm, as such overflows will carry a proportionate part of the untreated domestic sewage and industrial wastes.

Design of interceptors on the basis of a factor of the dry weather flow appears to be rational only to the extent of the degree of dilution applied to the sewage that is to overflow. The determination can be made more truly rational if provision is made for consideration of as many of the other influencing factors as it is feasible to evaluate.

A Proposed Rational Approach

The capacity of an intercepting sewer, Q_I, should be sufficient to provide for a dry weather flow, DWF, plus a storm water allowance, Q_S—that is,

$$Q_I = \text{DWF} + Q_S \qquad (1)$$

The rational formula for determining surface runoff is introduced into Eq. 1 by making the storm-water allowance, Q_S, equal to the product of the coefficient of runoff, C, a rainfall intensity, i, to be provided for in the intercepting sewer, and the area served,

A. Thus,

$$Q_S = CiA \qquad (2)$$

Consolidating Eqs. 1 and 2 gives

$$Q_I = \text{DWF} + CiA \qquad (3)$$

In Eq. 3 the dry weather flow, the runoff coefficient, and the contributing area are fixed and determined by local conditions. The rainfall intensity, i, varies with the time of concentration (rainfall duration) and with the storm frequency (probability of occurrence). This relationship is extant for lower frequencies and higher intensities than are developed in this investigation. Of these two variables on which intensity is dependent, the time of concentration is fixed and determined by local conditions. This leaves a single variable under the control and at the discretion of the designer; that is, to provide for a storm frequency not likely to be exceeded more often than determined by the designer.

It is necessary to establish the relationship between rainfall intensity and the time of concentration for various frequencies in order to properly evaluate the problem of how often overflow is to be permitted. Investigations did not disclose any compilation of the data at the frequency of occurrence that would be useful to the study, which is in the range of more than once a year. The problem was discussed with United States Weather Bureau personnel locally, and with the Division of Climatological and Hydrologic Services in Washington, D. C. For a small-scale exploratory investigation of this nature, it was found necessary to start from scratch in compiling the desired data from the Bureau's original triple-register record sheets. It was decided to work up these data only for a 3-year period, in order to evaluate the soundness and scope of the study. The step by step development follows:

First Step

A basic tabulation was prepared recording 0.01-in. units of precipitation occurring in successive 10-min. intervals for each period of rainfall through the years 1941, 1942, and 1944. These were taken from Weather Bureau daily records for Battery Place, New York City. The investigation of the year 1943 was omitted for present purposes because of extended interruption of the recordings at the station during that year.

There are three choices in procedure for tabulating the precipitation in successive 10-min. intervals. These are: (a) Each storm may be analyzed by successive 10-min. intervals as determined by the clock, in which case the first and last intervals usually would contain only a partial duration of precipitation; (b) each storm may be analyzed by starting the 10-min. intervals when the rain begins, in which case only the last usually will contain a partial duration of precipitation; and (c) each storm may be analyzed by first locating the 10-min. interval containing the maximum amount of precipitation and counting the remaining intervals from this one as a base, the first and last intervals possibly containing partial duration of precipitation. Data compiled herein were based on method (b).

Second Step

The second step was to tally all 10-min. amounts of rainfall of 0.01 in. or more as determined from the basic tabulation for each year. This second step was repeated for 20-min., 60-min., and 120-min. intervals for each of the three years indicated. Tallying rainfall in 20-, 60-, and 120-min. intervals could be accomplished either by combining the 10-min. amounts previously determined in the manner described below or by the longer procedure of re-analyzing the individual storms using choice (c) of the first step. Because the basic tabulation was set up in 10-min. units through each storm, the 10-min. tally was a straight count of recorded amounts in each 10-min.

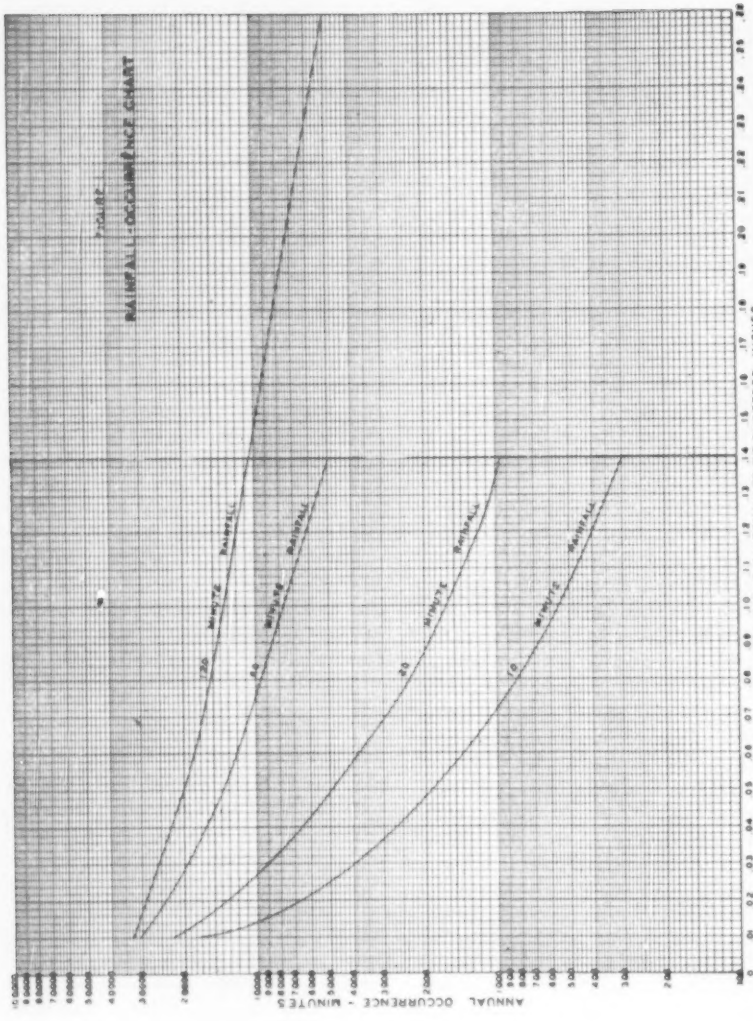

FIGURE 1.—Rainfall occurrence chart for various durations.

interval. However, in the tallies for multiple intervals (20, 60, and 120 min.) only peak amounts occurring in the respective tally periods were counted.

In this procedure, each storm is examined to determine the maximum amount of precipitation for the particular tally interval. Similarly, all other peaks or maximum amounts for the tally interval in the same storm are determined with the following provisos: (1) that any recordable amount (0.01 in. or more) occurring within a tally interval must be considered a peak; (2) that successive tally intervals cannot overlap to form peaks; and (3) that precipitation in any amount occurring in less time than the tally interval, and not included as part of a tally interval forming a peak, is discarded.

Third Step

Precipitation equalled or exceeded was plotted against annual occurrence. This was done for the 10-, 20-, 60-, and 120-min. periods for which tallies were made, as shown in Figure 1. The 120-min. curve was extended to obtain intensity limits required later in this report.

Fourth Step

Figure 2, plotted from data shown in Figure 1, shows the relation between the amount and the duration of rainfall for various annual occurrences. For convenience, the time element is expressed in hours and days, rather than in minutes as used in Figure 1. Thus, the 144-hr. (8,640 min.) occurrence line intersects the duration curves as follows:

Duration	Precipitation
10 min.	0.016 in.
20 min.	0.031 in.
60 min.	0.089 in.
120 min.	0.171 in.

Each curve of Figure 2 was plotted from only 4 points, as only the 10-, 20-, 60-, and 120-min. intervals were tabulated. Although the shape of the curve is well-defined, it is felt that more data should be tabulated to more accurately establish these curves.

Fifth Step

The time-intensity curves of Figure 3 were developed from Figure 2 by using the same abscissa and converting the ordinate, precipitation, to intensity by dividing by the duration. Smooth curves were drawn through points of equal frequency, which are indicated prominently to emphasize the sparsity of data on which the form of the curves is established.

The curves developed and presented herein are for illustrative purposes only. It is not intended that they represent either the most suitable type of graph for practical use or that they are representative of the shape of curve that will develop from a study of either another period of time or other weather stations. The limitations should be kept in mind in the comparative applications which follow.

Present Shortcomings as Shown by Rational Approach

In applying the factors generally used in the design of interceptors, consideration may be given to the effect of the overflow on the receiving waters; however, these factors do not relate directly to such consideration. Formulas based solely on the dry-weather flow have no direct relation to the rainfall accommodated, nor to the times per year that the overflow occurs, nor to the capacity of the receiving waters to assimilate the pollution thus discharged into them. Although pollution in storm-sewage overflows is diluted, it must be recognized that there may be times and places where the amount of such pollution being discharged into the watercourse without treatment is

a factor to be reckoned with. When a standard for the design of interceptors is based on a factor of the dry-weather flow alone, the effect of variations in population density, runoff and other factors for areas compared can be appreciable. Some typical designs within the Interstate Sanitation District have been selected to illustrate this point.

The design of the Manhattan Interceptor, New York City, provides for twice the average dry-weather flow.

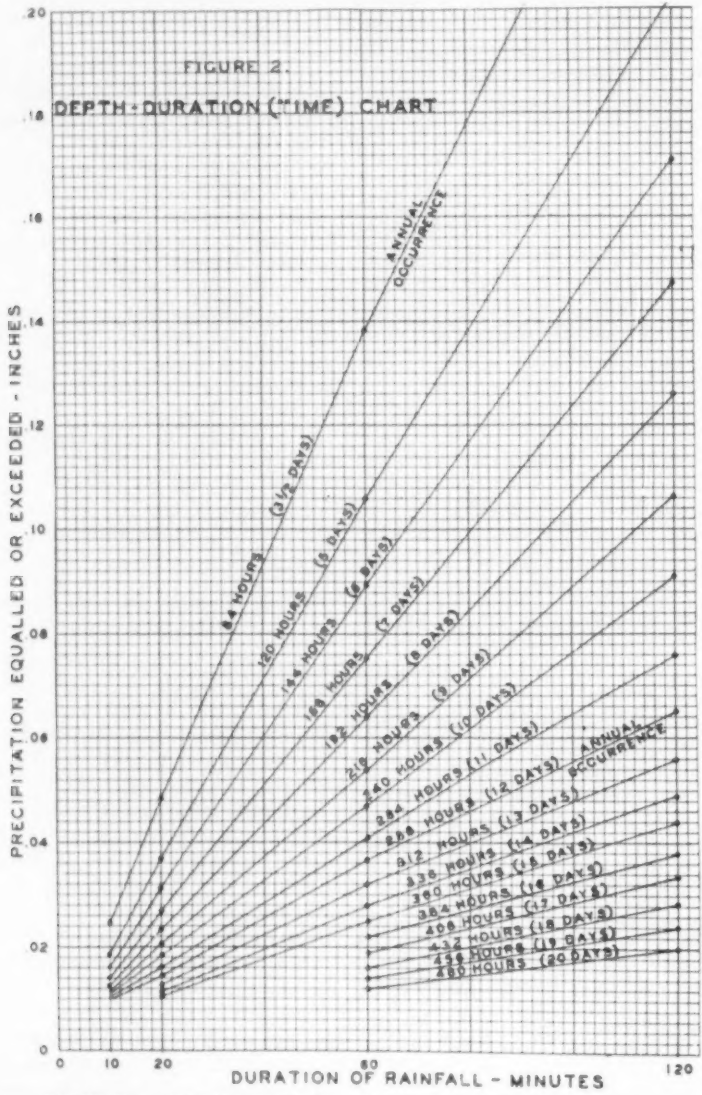

FIGURE 2.—Depth-duration chart for various rainfall occurrences.

Therefore, provision is made for storm water in an amount equal to the average dry-weather flow. The interceptor has two branches, which converge at East 110th Street. The north branch interceptor, from 179th Street to 110th Street, has a time of concentration of 2 hr. 8 min. and provides for 206 sec.-ft. of storm water; this allows for a computed rainfall intensity of 0.081 in. per hr. The south branch interceptor, from 73rd Street to 110th Street, has a

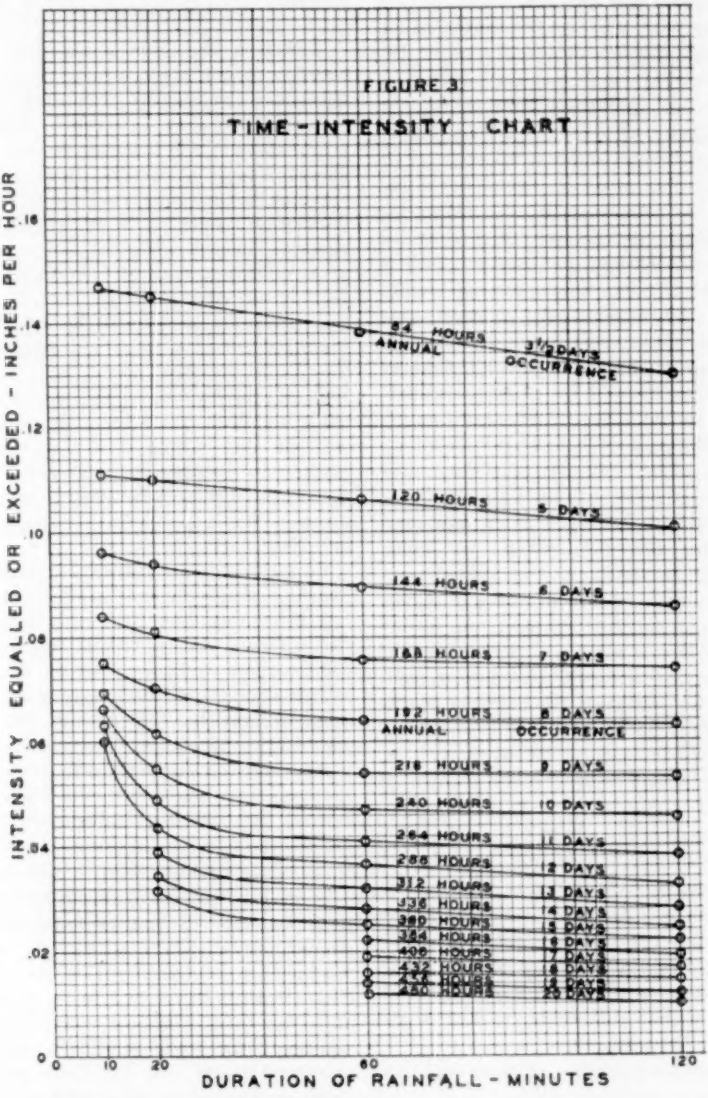

FIGURE 3.—Time-intensity chart for various rainfall occurrences.

time of concentration of 1 hr. 14 min. and provides for 138 sec.-ft. of storm water; this allows for a computed rainfall intensity of 0.062 in. per hr. From the tentative curves shown in Figure 3 it is estimated that the north branch interceptor will overflow a total of 154 hr. per year, whereas the south branch interceptor will overflow a total of 197 hr. per year—a 28 per cent difference in over-all pollution time using the same factor of the dry-weather flow as basis of design for each branch.

A similar analysis was made of the plans for Bayonne, N. J., where the intercepting sewers are designed on the basis of 1,000 gal. per capita. This is equivalent to approximately eight times the (computed) average dry-weather flow. The Bayonne northeast interceptor has an estimated time of concentration of 1 hr. 47 min. and provides for 94.8 sec.-ft. of storm water; this allows for a computed rainfall intensity of 0.119 in. per hr. The southeast interceptor has an estimated time of concentration of 1 hr. 9 min. and provides for 40.6 sec.-ft. of storm water; this allows for a computed rainfall intensity of 0.14 in. per hr. Again referring to the tentative curves of Figure 3, it is estimated that the northeast interceptor will overflow a total of 94 hr. per year, whereas the southeast interceptor will overflow a total of approximately 84 hr. per year.

In a recent design by the Bureau of Sewers of Brooklyn, N. Y., with a time of concentration of 22 min., provision was made for a maximum capacity of approximately three times the average dry-weather flow; this allows for a computed rainfall intensity of 0.069 in. per hr. On the basis of the tentative curves of Figure 3 it is estimated that overflow will occur for a total of 192 hr. per year.

A tabular summary of these findings shows:

Place	Factor times Dry Weather Flow	Equivalent Intensity (in. per hr.)	Overflow (hr. per yr.)
North Branch, Manhattan	2	0.081	154
South Branch, Manhattan	2	0.062	197
Bayonne, N.E.	8	0.119	94
Bayonne, S.E.	8	0.140	84
Brooklyn	3	0.069	192

Although the curves showing the overflow hours per year are tentative because of the sparsity of rainfall data, it is felt that they do serve to demonstrate some of the inconsistency of the common basis of design. Such differences as are demonstrated would be of particular concern to a regulating agency charged with the problem of area pollution control. Witness the fact, in the example cited, that Brooklyn, where facilities will be available for three times the average dry-weather flow, will overflow more than North Branch, Manhattan, where provision is made for only twice the average dry-weather flow. Note also the disproportionate relationship between the factor of dry weather flow and the overflow hours per year for Bayonne and New York.

Caution should be exercised against drawing of specific conclusions or making interpretations from this tabulation. Other considerations, including dilution and diffusion factors at the several points of discharge, may require evaluation. The authors are not yet in a position to say that the interceptors are of adequate size with respect to the conditions which should prevail in the particular receiving waters.

Comments

It has been the intent throughout this paper to stress the limited scope of the present investigation, which has been confined to a consideration of four time elements developed from rainfall data for three years at one weather station. This study is still in an exploratory stage and has been predicated on the relationship between the

coefficient of runoff and the duration and intensity of rainfall generally accepted in storm sewer design where much higher intensities of rainfall are normally considered. As the opportunity is presented, the study may be made more comprehensive and should, among other factors, include more detailed study of the relationship between the runoff factors and the low-intensity rainfall herein involved.

Rainfall data currently published by the U. S. Weather Bureau are tabulated in terms of amount by hourly intervals and served no specific use in the intensity-frequency determinations. Data within the desired range are recorded on the Bureau's original triple register record sheets, but are not compiled for publication. For the purpose of this study Weather Bureau personnel were consulted on tabulating procedures before embarking on a private compilation of the 3-year record used in the study.

Conclusions

This limited investigation into the feasibility of developing a rational basis of design of intercepting sewers for use with combined sewer systems indicates that the approach proposed herein has possibilities that may be encouraging. It suggests a rational approach to determining the capacity of such intercepting sewers, in which is employed the same basic character of time-intensity curve as that now used in storm drain design. It provides a means of designing the capacity of these intercepting sewers with a knowledge of the probable quantity or frequency of overflow and resulting pollution. The proposed method is rational and appears to have definite and practical application. From the basic tabulation, many types of charts can be prepared to show, for example, the quantity of overflow, the total time of overflow, and the frequency of overflow for any specified interval of time.

The development of the rational method offered will permit a more satisfactory means of designing interceptors with due regard to the effect of the storm overflow on the receiving waters.

OHIO CERTIFICATION EXAMINATIONS

The Ohio Department of Health has announced that examinations for operator certification, grades A, B, and C, in both water and sewage treatment, will be held on April 28, 1950, in Massillon, Cincinnati, Cleveland, Columbus, and Toledo. Applications must be filed by March 18, 1950, on blanks furnished by the Department.

Qualifications to take the examination have been extensively amended, with experience credit now being given for satisfactory completion of the Short School for Operators. Complete information is available from the Ohio Department of Health, Ohio Departments Building, Columbus 15, Ohio.

THE POLLUTIONAL EFFECTS OF STORM-WATER OVERFLOWS FROM COMBINED SEWERS*

By Clyde L. Palmer

Sanitary Engineer, City Engineer's Office, Department of Public Works, Detroit, Mich.

Introduction

Within the last few years, there has arisen a popular demand for the abatement of stream pollution and all sanitarians certainly agree with this movement in principle. As is often the case, however, the tremendous surge of an awakened public interest may carry any cause far beyond justifiable limits. The demand is made that all pollution must be abated without evaluating the cost of the damage that would result by depriving individuals or municipalities of the reasonable use of their water resources. Pollution caused by storm water overflows from combined sewer systems has been condemned and perhaps rightly so, but before public or private resources are dissipated in an effort to eliminate entirely all stream pollution, it might be well to appraise the problem both as to the possibilities of reaching the ideal objective and the results that can be accomplished within practical limits.

In the discussion of the problem of abating stream pollution, little if any distinction is made between the pollution caused by storm water overflowing from a combined sewer system operating in conjunction with diversion works and sewage treatment facilities and the pollution caused by the direct and continuous discharge of sanitary sewage to receiving waters.

The case against the direct and continuous discharge of sanitary sewage has long since been proven, and as to the necessity for abatement, all sanitarians agree. The nature, extent, and methods of abatement of the pollution caused by storm overflows from combined sewers are not so well defined and are the subject of this discussion.

Characteristics of Low-Intensity Storms

Preliminary to the study of the pollutional effects of storm-water overflows from combined sewers, it is necessary to investigate the characteristics of low-intensity storms, which are obviously the most numerous, and, consequently, the most important in this particular study. The accompanying diagrams were prepared from the data of the U. S. Weather Bureau and City of Detroit records. Figure 1 indicates that 90 per cent of the annual rainfall in the Detroit area is contributed by storms having an intensity of 0.50 in. per hr. or less, and about 50 per cent by rainfall of 0.10 in. per hr. or less. Figure 2 indicates that, on the average, 157 storms occur per year in amount of a trace or more, and that about 89 storms per year occur that are 0.03 in. or more in amount. Figure 3 indicates that, on the average, 14 per cent of the total time at least a trace of rain is falling, and 3 per cent of the time, it is raining 0.03 in. per hr. or more.

In studying the results of the foregoing storm data, it is first assumed that the effects of rainfall will be imposed on a combined sewer system provided with diversion works to pass the sanitary flow to the collecting inter-

* Presented at 24th Annual Conference, Michigan Sewage Works Association; Traverse City, Mich.; May 23-25, 1949.

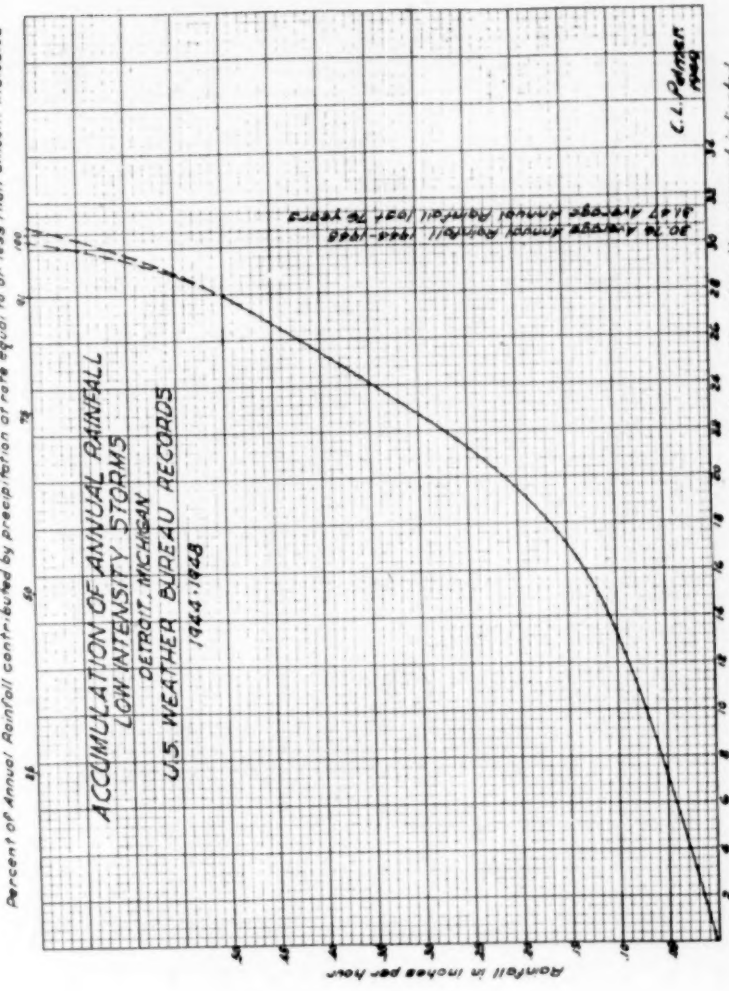
ACCUMULATION OF ANNUAL RAINFALL
LOW INTENSITY STORMS
DETROIT, MICHIGAN
U.S. WEATHER BUREAU RECORDS
1944-1948
Percent of Annual Rainfall contributed by precipitation at rate equal to or less than amount indicated
Inches of Annual Rainfall contributed by precipitation at rate equal to or less than amount indicated
Rainfall in inches per hour
C.L. Palmer

FIGURE 1.—Accumulation of annual rainfall in low intensity storms at Detroit, Mich.

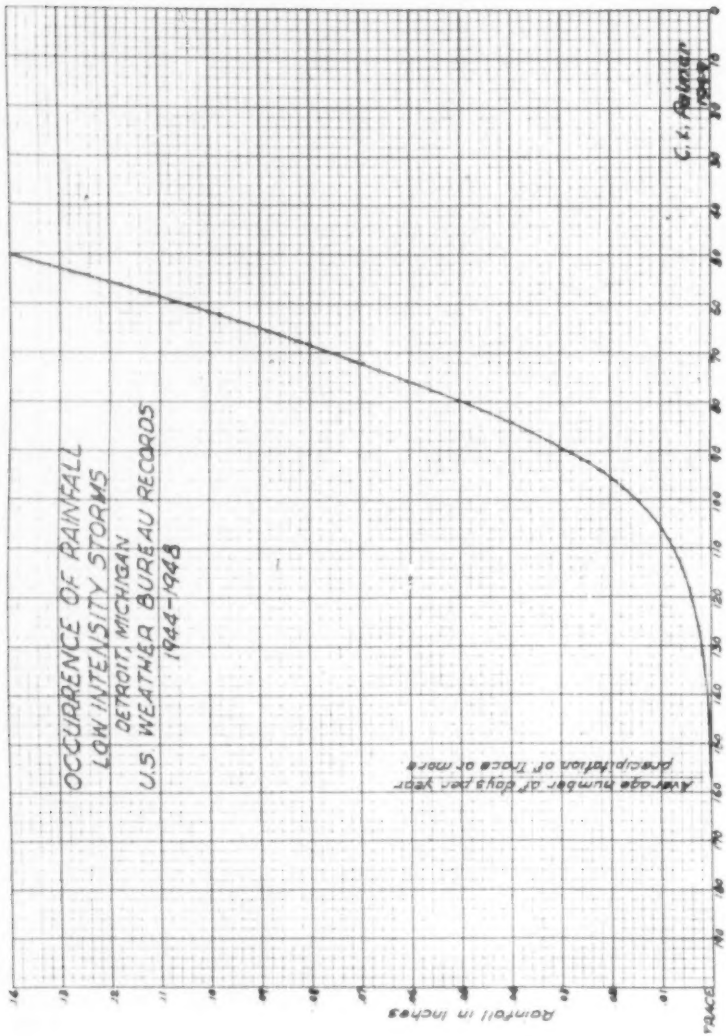
OCCURRENCE OF RAINFALL
LOW INTENSITY STORMS
DETROIT, MICHIGAN
U.S WEATHER BUREAU RECORDS
1944-1948
Rainfall in inches
Average number of days per year
precipitation of Trace or more
Average number of days per year rainfall equalled or exceeded amount indicated

FIGURE 2.—Occurrence of rainfall in low intensity storms at Detroit, Mich.

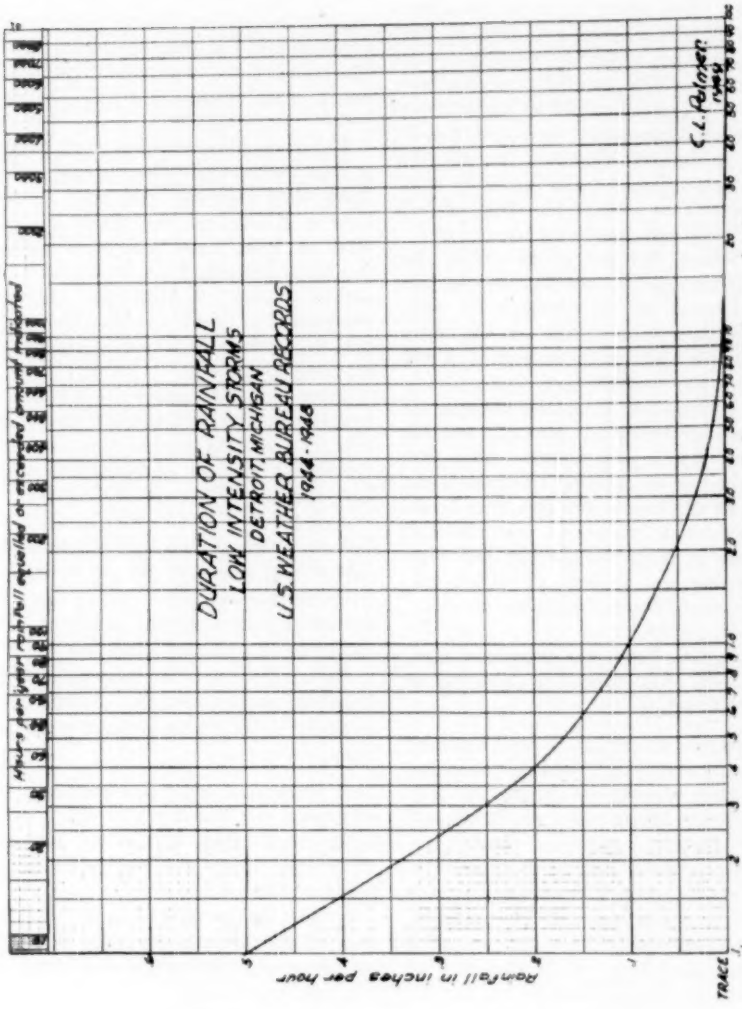

FIGURE 3.—Duration of rainfall in low intensity storms at Detroit, Mich.

ceptor system and to the treatment plant.

It is obvious that some of the very light rainfalls will not even reach the sewers. The limits of storm intensity for which this is true had to be determined in order to establish the point at which rainfall could affect the sewer system. Data on the amount of rainfall necessary to cause runoff were accumulated by field observation and measurement using portable rain gauges. The result of the observations thus made indicated that, on the average, runoff did not occur unless the precipitation exceeded 0.03 in. per hr.

Inasmuch as the analysis of conditions was to be made on the basis of quantity of flow in multiples of the average dry-weather flow, this quantity was determined from the records of the sewage treatment plant at Detroit as 162 g.p.d. per capita. This flow then had to be expressed as inches per hour on the area to evaluate it in terms equivalent to rainfall. For Detroit conditions, with 40 people per acre producing an average of 162 g.c.d., the sanitary flow is equivalent to about 0.01 in. per hr.

Reasoning from the foregoing computations, the following conclusions can be reached:

1. Before storm runoff from the land to the sewer system occurs, precipitation must exceed 0.03 in. per hr.

2. Before storm-water overflows will occur from a combined sewer system to receiving waters, the precipitation must exceed 0.03 in. per hr. plus whatever storm capacity the interception has over and above that required for sanitary flow or, in the case of Detroit, an additional 0.01 in. per hr. for each multiple of the sanitary capacity available for storm flow; for example, with an interception capacity of twice the sanitary flow, storm overflow would not occur unless the precipitation exceeded 0.04 in. per hr. (0.03 + 0.01). With an interception capacity of three times the sanitary flow, the precipitation would have to exceed 0.05 in. per hr. (0.03 + 0.02) before overflow would occur, and so on.

In order to get some check on the above method of computation, a study was made of the records of the Conner Creek storm pumping station at Detroit.

Figure 4 gives the pumping record at that station and indicates that storm flows that required pumping to the Detroit River occurred about 2.5 per cent of total time and at a pumping rate equivalent to about 0.04 in. per hr. on the tributary area. Storms producing a pumping rate less than 0.04 in. per hr. could be diverted to the interceptor system.

From the data shown in Figures 2 and 3 and the finding that no runoff will be produced by precipitation under 0.03 in. per hr. and that the average sanitary flow of 162 g.c.d. is equivalent to 0.01 in. per hr. of rainfall, computations can be made relating interceptor capacity in multiples of average sanitary flow (162 g.c.d.) to occurrence of overflows per year and duration of overflows per year.

Figure 5 shows the relation between overflow occurrence and interceptor capacity. The following points are of note:

1. With no storm-water diversion, 89 overflows per year might occur. In other words, there are on the average 89 storms when the precipitation is greater than 0.03 in.

2. With interceptor capacity 600 per cent of the average sanitary flow, 65 overflows per year might still occur to the receiving waters.

3. An interceptor with a capacity 600 per cent of the sanitary flow would reduce the number of overflow occurrences 25 per cent.

4. Relating the reduction of overflow occurrences to the capacity of the interceptor shows that each g.c.d. unit

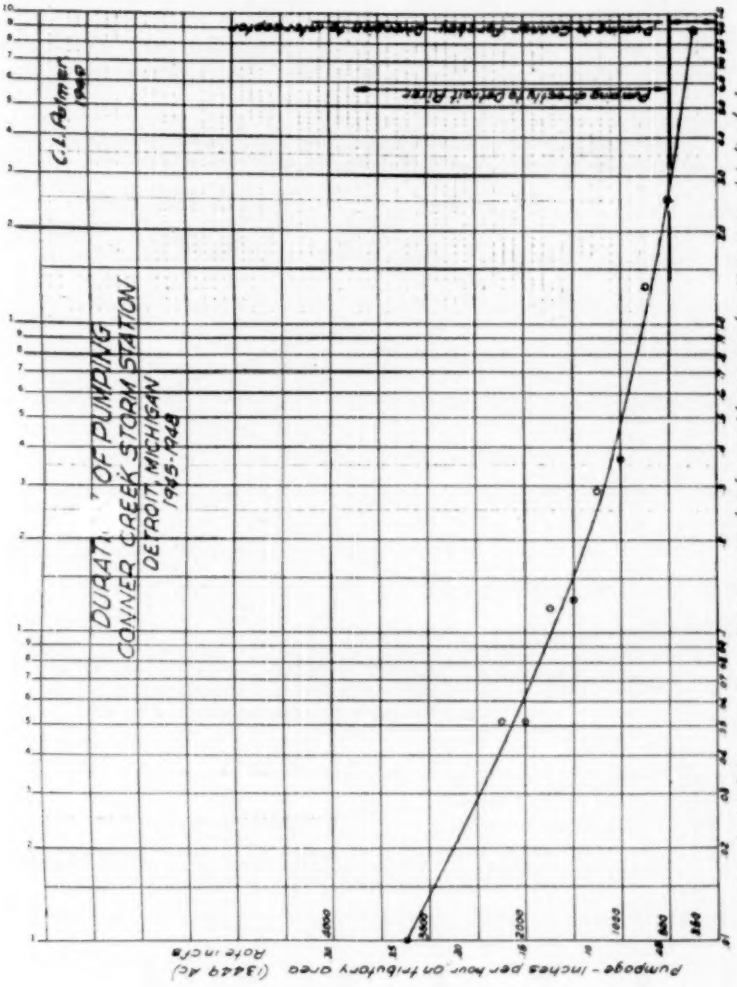
DURATION OF PUMPING
CONNER CREEK STORM STATION
DETROIT, MICHIGAN
1945-1948
C.L. Palmer
1949
Pumping directly to Detroit River
Pumping to Conner Pumping Station to Detroit River
Percent of total time pumping in progress at rate equal to or greater than amount indicated
Pumpage - inches per hour on tributary area (1344.9 Ac)
Rate in cfs

FIGURE 4.—Duration of pumping at Conner Creek storm station.

of interceptor capacity is most effective when the interceptor capacity is 150 per cent of the sanitary flow or it may be stated that the interceptor is most effective in preventing overflow occurrence, gallon for gallon of capacity, when it has a capacity of 150 per cent of the sanitary flow.

Figure 6 shows the relation between overflow duration and interceptor capacity. The following points are of note:

1. With no storm-water diversion, the duration of storm-water overflows would occupy 3.0 per cent of total time. In other words, on the average,

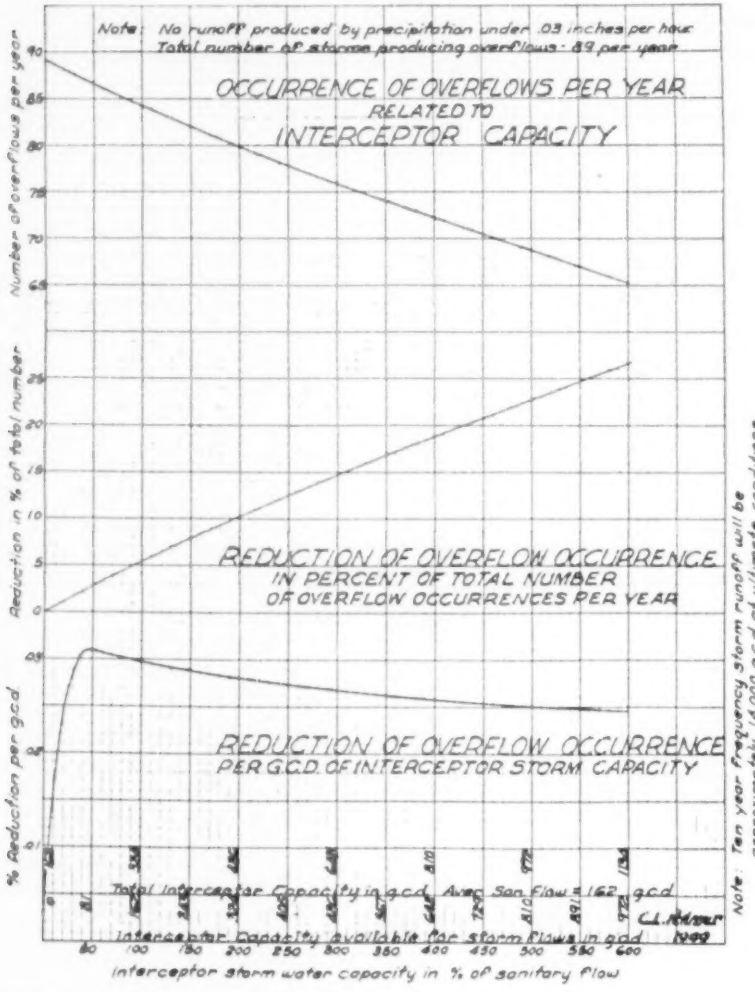
Note: No runoff produced by precipitation under .03 inches per hour
Total number of storms producing overflows: 89 per year
OCCURRENCE OF OVERFLOWS PER YEAR
RELATED TO
INTERCEPTOR CAPACITY
Number of overflows per year
REDUCTION OF OVERFLOW OCCURRENCE
IN PERCENT OF TOTAL NUMBER
OF OVERFLOW OCCURRENCES PER YEAR
Reduction in % of total number
REDUCTION OF OVERFLOW OCCURRENCE
PER G.C.D. OF INTERCEPTOR STORM CAPACITY
% Reduction per g.c.d.
Total Interceptor Capacity in g.c.d. Avg. San. Flow = 162 g.c.d.
Interceptor Capacity available for storm flows in g.c.d.
Interceptor storm water capacity in % of sanitary flow
Note: Ten year frequency storm runoff will be approximately 1,000 g.c.d. at ultimate conditions

FIGURE 5.—Relation of overflow occurrence and reduction to interceptor capacity as a function of sanitary flow.

precipitation in excess of 0.03 in. per hr. occurs for 3.0 per cent of total time.

2. With interceptor capacity 600 per cent of the average sanitary flow, the duration of overflow would be reduced to 1.0 per cent of total time.

3. An interceptor with a capacity 600 per cent of the sanitary flow would reduce the duration of overflows 60 per cent.

4. Relating the reduction of overflow duration to interceptor capacity shows that each g.c.d. unit of interceptor capacity is most effective when the interceptor capacity is 150 per cent

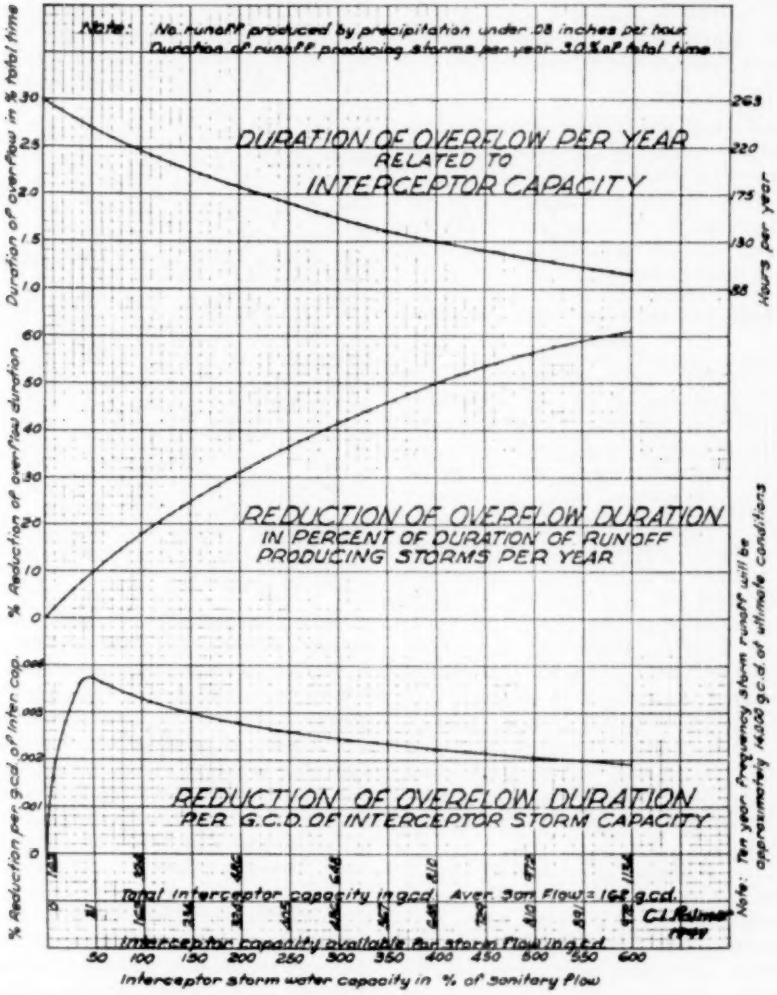
Note: No runoff produced by precipitation under .08 inches per hour
Duration of runoff producing storms per year 3.0% of total time
DURATION OF OVERFLOW PER YEAR
RELATED TO
INTERCEPTOR CAPACITY
Duration of overflow in % total time
Hours per year
REDUCTION OF OVERFLOW DURATION
IN PERCENT OF DURATION OF RUNOFF
PRODUCING STORMS PER YEAR
% Reduction of overflow duration
REDUCTION OF OVERFLOW DURATION
PER G.C.D. OF INTERCEPTOR STORM CAPACITY
% Reduction per g.c.d. of inter cap.
Note: Ten year frequency storm runoff will be approximately 4,000 g.c.d. of ultimate conditions
Total interceptor capacity in g.c.d. Aver. Storm Flow = 168 g.c.d.
C.I. Palmer 1949
Interceptor capacity available for storm flow in g.c.d.
Interceptor storm water capacity in % of sanitary flow

FIGURE 6.—Relation of overflow duration and reduction to interceptor capacity as a function of sanitary flow.

of the sanitary flow (that the interceptor is most effective in reducing the duration of overflow, gallon for gallon of capacity, when it has a capacity of 150 per cent of the sanitary flow).

The foregoing analysis of the effect of storm-water diversion to interceptors as a method for abatement of the pollution resulting from storm-water overflows from a combined sewer system and summarized in Figures 5 and 6 leads to the following conclusions:

1. No satisfactory reduction in the number of storm overflow occurrences can be made by any reasonable increase in interceptor capacity.
2. No satisfactory reduction in the duration of storm overflows can be made by any reasonable increase in interceptor capacity.

Quality of Overflow from Combined Sewers

The conclusions reached as to the effectiveness of increasing interceptor capacity in reducing storm-water overflow occurrences and duration of overflows did not consider the quality of the overflow storm water and whether the diversion of a greater number of the smaller storms and an increased portion of larger storms would accomplish the feat of preventing a disproportionately greater amount of pollution from escaping with the storm-water overflow. The conclusion reached by some observers that the quality of overflow storm water from a combined sewer shows high pollution during the early period of overflow, diminishing as the overflow continues, has not been substantiated in the studies made at Detroit.

The collection of data for Detroit has not been completed to the extent that positive conclusions have been reached, and only a limited range of storm intensities have been investigated. However, the results obtained on a large and extensive sewerage system appear to be affected by factors not so significant in simple systems, and the following conclusions have been at least partially substantiated:

1. Erratic variations in the quality of overflow storm water are characteristic and result from the time element involved in arrival at the point of overflow of the first flush water from the tributary systems discharging to the main trunk sewer. This effect appears particularly significant in an area such as Detroit, where the time of concentration in the larger sewer systems is as long as 200 min.
2. A condition of more or less uniform quality of overflow storm water cannot be expected unless the storm period substantially exceeds the time of concentration of the sewer system and in sufficient intensity to maintain high velocities.
3. After the storm flow has exceeded the capacity of the diversion to the interceptor of 2 to 2.5 times the dry weather flow, the quality of the overflow water will have about the following characteristics: Coliform indices (m.p.n.), 4,300,000; 5-day B.O.D., 50 p.p.m.; suspended solids, 250 p.p.m.; and suspended volatile solids, 100 p.p.m. Plus variations of 100 per cent and minus variations of 50 per cent are to be expected.

From the study of the quality of overflow storm water, the conclusion is reached that no satisfactory reduction in the pollution carried by storm-water overflow can be accomplished by any reasonable increase in interceptor capacity, due to the fact that diminution of pollution after the first flush does not obtain and successive peaks of pollution arrive later in the progress of the storm overflow.

Separate Storm Sewers

The separate system of sewerage has been advanced as a solution for the problem of abatement of the pollutional effects of storm overflows from combined sewers. A study of the re-

sults to be expected from a separate system brings up the questions of cost, results in abating pollution, and operational problems inherent in separate systems.

In an area where the topographical relief is not pronounced, the construction cost of a separate system of public sewers is estimated to be about twice the cost of a combined system, assuming new construction in an unsewered area. In an area sewered on the combined system, there would be an additional cost to individual householders, over and above the cost of the public collecting system, amounting to at least $500 each. For example, Detroit's combined sewer system to date has cost $100,000,000. If it were to be changed to a separate system, an additional $100,000,000 of public funds would have to be expended for sanitary sewers and appurtenances. In addition, the 270,000 households now connected to the combined system would have to separate their sanitary plumbing from their storm plumbing at an estimated cost of $500 each or a total of $135,000,000.

With expenditures of this magnitude indicated, overwhelming justification must be presented in support of the benefits to be accomplished by a separate system.

In studies made at Detroit to determine the quality of storm water that could be expected from a separate system, samples of storm-water runoff from the land surface were collected at points of concentration near catch basin inlets and analyzed. Although the study has not been completed and the number of samples taken and the types of areas studied are limited, it appears that the storm runoff from the land surface is polluted to the extent that the storm-water flows from a separate storm sewer could be expected to be very unsatisfactory under the same standards by which the quality of storm overflows from combined sewers are judged.

The first samples analyzed indicated such high coliform indices that doubt was cast on the type of organisms found, and, subsequently, Tryptose broth was used and B.O.D. determinations made on the samples to give better confirmation of the results. The results of a sampling taken at a catch basin in the business district of Detroit during a rain storm on March 22, 1949, are as follows:

Sample	Time (A.M.)	M.P.N.	Total Solids (p.p.m.)	Vol. Solids (p.p.m.)	5-Day B.O.D. (p.p.m.)
1	8:55	930,000	660	299	234
2	9:05	430,000	715	331	—
3	9:15	430,000	726	340	124
4	9:30	930,000	462	194	—
5	9:45	430,000	914	414	132
6	10:00	230,000	430	202	—
7	11:25	43,000	714	370	96
8	11:32	25,000	310	136	—

Although the data collected to date may not be conclusive, the evidence indicates that more exhaustive investigation must be made before huge expenditures for separate sewer systems can be recommended.

The operational problems involved in maintaining a separate system as a separate system have not been successfully solved, particularly in large and extensive systems. Either by stealth, or ignorance, or good intention, sanitary connections improperly find their way into storm sewers where the separate system is in use. Large systems would require policing on a major scale to discover sanitary connections made surreptitiously into the storm sewers, and experience at Detroit indicates that a completely separate storm and sanitary sewer system can never be successfully protected from this type of misuse.

From a study of the results to be expected from the use of separate storm sewers, it is concluded that:

1. The cost of a separate system is prohibitive and not commensurate

with the results possible to achieve.

2. The quality of the storm water from a separate storm sewer serving an area such as Detroit would be very unsatisfactory and highly polluted.

3. Separate storm sewers are practically impossible to maintain as such without some sanitary flow being included.

Storm-Water Treatment

The treatment of the overflow storm water from a combined sewer system has been advocated as a solution of the problem of pollution from this source. The results as to quality of the storm water after treatment that could be expected from this solution of the problem obviously would be those that could be determined in advance by design.

The results as to total over-all benefits would be effective for about 2 per cent of total time. In other words, any facility provided or expenditures made would be useful and a benefit for the duration of the pollutional effect only which would be for about 2 per cent of total time, during which time about 1 per cent of the sanitary flow escapes to the receiving waters.

Studies made at Detroit indicate that to prevent the 1 per cent of pollution entering the Detroit River from the combined sewer system would require storm-water treatment structures estimated to cost about $2,000,000 per 1,000 c.f.s. of treatment capacity, and an annual operating and maintenance cost of $60,000 per 1,000 c.f.s. of treatment capacity.

In addition to the high cost, the method has another undesirable feature in the multiplicity of treatment installations that would be required. Detroit has about 50 storm-water overflow outlets along the highly developed Detroit River waterfront, with a total capacity of about 50,000 c.f.s. The construction of storm-water treatment plants in these areas would be difficult, expensive, and objectionable. Although no conclusions have been reached, the following comparison can be made relative to storm-water treatment as a means of abating pollution resulting from storm overflows from a combined sewer system:

1. Satisfactory quality standards can be met as a matter of proper design and operation of the storm-water treatment facilities provided.

2. It appears to be the least expensive of any of the solutions presently available.

3. The main objectionable feature of this method is the multiplicity of treatment plants required, and this problem remains to be solved.

Conclusions

The pollutional effects of storm water overflowing from a properly designed combined sewer system with diversion and regulation to an interceptor and sewage treatment system result from storm overflows that in themselves occur only about 2 per cent of total time, during which time about 1 per cent of the total sanitary sewage of the drainage area escapes into the receiving waters. It should be noted that during the 2 per cent of total time that overflow is occurring not all of the sanitary flow is escaping.

The dilutional effect of the storm-water vehicle carrying the sanitary sewage to its escape into the receiving waters has been shown to be insufficient to reduce the pollution to acceptable standards. The dilutional effect of the receiving waters in some cases may be sufficient to prevent serious local nuisance; however, the effectiveness of this process of purification is limited to those conditions where a long time factor intervenes between the point of overflow and the affected area when such uses of the receiving waters as water supply or recreation are involved. The effect of increasing the amount of diversion to interceptors is clearly shown by this study to be insignificant within the range of reasonable cost and practical size structures.

It appears from this study of the problem that properly designed regulation and diversion of a combined sewer system will be about 99 per cent effective in preventing pollution resulting from the use of this type of sewerage system. The use of a separate sewer system may be effective in small systems and suburban areas, but the results of this study indicate that for extensive systems and densely populated areas the cost of a separate system is prohibitive and the results to be expected from such a system are entirely unsatisfactory.

It is the conclusion of this study that where conditions are critical and greater protection from pollution than that accomplished by proper diversion of sanitary flow is warranted, the most effective method appears to be storm water treatment at the individual outlets or at a common outlet for several adjacent systems.

POLLUTION OF LONG ISLAND SHELLFISH AREAS

The pollution problems of the shellfish industry of Long Island, N. Y., were reviewed in a paper presented at a meeting of the Long Island Section, New York State Sewage Works Association, on December 8, 1949, by M. H. Bidwell, shellfish bacteriologist, New York State Conservation Department. Reasons for the concern of regulatory and conservation agencies over pollution of the shellfish areas are more readily apparent when it is realized that the 1948 production of clams, mussels, and oysters was valued at more than $8,000,000, with an additional $2,100,000 in crabs, lobsters, seed oysters, and scallops.

Although wastes of human and industrial origin constitute a pollutional menace of significant proportions in some areas, hundreds of acres of very productive shellfish grounds are polluted mainly by wastes originating at the many duck farms of the eastern half of Long Island. Pathogens involved in the duck wastes are of the Salmonella group, which in humans can cause an intestinal disease resembling typhoid fever. Experiments have shown that plain settling for about one hour, followed by chlorination, will eliminate most of the objectionable duck waste solids that have formed sludge deposits in the bays, and with them most of the bacteria.

Two other sizeable sources of pollution in certain areas are the thousands of pleasure and commercial craft using these waters and discharging untreated sewage, and the overflowing cesspools and cesspools in ground water close to the shore. These sources are often extremely difficult to find and regulate.

Classification of the tidal waters involved, under the Water Pollution Control Bill passed by the New York Legislature in 1949, will automatically apply to each area various physical, chemical, and bacteriological standards. Proceedings to enforce compliance with these standards may necessitate secondary treatment in many existing treatment plants now affording only primary treatment.

MATHEMATICAL RELATIONSHIPS IN SEWAGE TREATMENT

By Ralph J. Bushee

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This paper is a discussion of a group of mathematical expressions relating to sewage treatment processes. The basic equations for this group consist of:

Case I $dp = K\,(s + m\,p)\,dt$ (1a)
Case II $dp = K\,C\,(1 - p)\,dt$ (2a)
Case III $dp = K\,(s + m\,p)\,(1 - p)\,dt$ (3a)

In these equations p is the proportion that the total action has gone to completion, as measured by the proportion of food material that has been destroyed; conversely, $1 - p$ must be the amount of food left per unit of food at the start; s is the amount of seed material for each unit of food material present at the start; m is the amount of seed material formed per unit of food destroyed; t is the elapsed time; C is a constant for the rate of reaction (in Cases I and III this constant is included in s and m); K is a constant expressing the effect of conditions not standard, notably temperature; and dp/dt is the rate at which the action is occurring.

Although the amount of food present at the start and that used up in time t are the basic measurements of the processes herein studied, in many cases the values of these units are obtained by indirect measurements. Among such measurements are: the amount of oxygen used up, the amount of gas produced, the oxidation or reduction of compounds, the change in the ratio of volatile to fixed solids, the number of bacteria present, or any other method the observer may select, if it can be assumed that the destruction of the food is measured reasonably closely by the indirect method selected.

Each of the above equations may be solved for p by dividing both sides of the equations by the terms involving p, and integrating. The constant of integration is obtained by noting that when $t = 0$, $p = 0$.

The values of p thus found for the three cases are given in Col. c, Table I, and are designated as Eqs. 1c, 2c, and 3c. Solving for t results in the values in Col. b. The values in Col. d were obtained by substituting these values of t in the original equations.

Case III has a point of inflection, the location of which is given by Eqs. 3e and 3f, and the value of which is given by Eq. 3g.

Example of Case I

Only one example of each case is presented. Case I results from the reduction of sulfates to sulfides in sewage to which sulfate has been added. This bacterial reduction was measured by Pomeroy and Bowlus (1) and the results as plotted by them are given in Figure 1. To correspond with the form of the equation as given herein, sulfates reduced were substituted for sulfides produced by multiplying the quantities given by 3, as 3 p.p.m. of sulfates are equivalent to 1 p.p.m. of sulfide. The excess of 15 or 16 p.p.m. of sulfides produced, corresponding to 45 to 48 p.p.m. of sulfates, must, as pointed out (1), be due to sulfur compounds present in the sewage in addition to the sulfates added. In order to plot the results in the form used by the authors, it is necessary to multiply both sides of Eq. 1a by F, the total amount of food present at the start, and to use f to represent $p\,F$, the total

TABLE I.—Basic Equations and Derived Formulas for Three Rates of Metabolism.

CASE	(a) BASIC EQUATIONS	(b)	(c)	(d)
	dp/dt EQUALS	t EQUALS	p EQUALS	dp/dt EXPRESSED AS t
I	$K(s+mp)$	$\frac{1}{Km}\log_e\frac{s+mp}{s}$	$\frac{s}{m}(e^{mkt}-1)$	Kse^{mKt}
II	$K(1-p)$	$\frac{1}{K}\log_e\left(\frac{1}{1-p}\right)$	$\frac{(e^{Kt}-1)}{e^{Kt}}$	Ke^{-Kt}
III	$K(s+mp)(1-p)$	$\frac{1}{K(s+m)}\log_e\frac{s+mp}{(1-p)s}$	$\frac{s(e^u-1)}{se^u+m}$	$Kse^u\frac{(s+m)(1+m)}{(se^u+m)^2}$
			$u=tK(s+m)$	

K = CONSTANT OF REACTION
p = PROPORTION OF TOTAL FOOD AVAILABLE WHICH HAS BEEN CONSUMED
s = AMOUNT OF SEEDING MATERIAL PRESENT PER UNIT OF FOOD WHEN $t=0$
t = TIME

CASE III HAS A POINT OF INFLECTION AS FOLLOWS:

$$dp/dt = K\frac{(s+m)^2}{4m} \quad (3g)$$

$$p_i = \frac{m-s}{2m} \quad (3e)$$

$$t_i = \frac{1}{K(s+m)}\log_e\frac{m}{s} \quad (3f)$$

amount of food used up in the time t. Thus,

$$F\,dp/dt = K\,(s\,F + m\,p\,F) \quad (4a)$$

Substituting S, the total amount of seed material present at the beginning, for $s\,f$, f for $p\,F$, and df for $F\,dp$, Eq. 4a becomes

$$df/dt = K\,(S - m\,f) \quad (4b)$$

which when solved to the form of Eq. 1b becomes

$$t = \frac{1}{K\,m}\log_e\frac{S + m\,f}{S} \quad (4c)$$

By cut and fit a formula—

$$t = \frac{1}{0.00768}\log_e\frac{0.1616 + 0.00768\,f}{0.1616} \quad (5)$$

—was obtained to fit the results. This was plotted after simplifying to

$$t = 300\,\log_{10}\,(1 + .0476f) \quad (6)$$

Eq. 5 in the form of Eq. 1b as modified above, is shown in Figure 1, together with the results of the experiments as taken from the published curve (1). The reaction proceeds independently of the amount of food present until a point is reached where apparently the scarcity of food slows the rate of the reaction, as indeed it must at some time. There were not enough points given to locate accurately the point of inflection, but it appears to occur when about 75 to 85 per cent of the total action has elapsed.

It is not difficult to find chemical and biological actions with larger organisms which parallel the reaction of Case I. A self-catalyzing chemical reaction would produce a similar equation, and so would the geometrical increase curve of all life where the rate of increase is constantly proportional to the population.

Example of Case II

The classic example of Case II is, of course, Phelps' formula for the self purification of sewage. The formula (2) is usually expressed as

$$L_t/L = 10^{-kt} \quad (7)$$

in which L is amount of food present at the start and L_t is the amount of food left at time t. This can be reduced to

$$(F - f)/F = 1 - f/F$$
$$= 1 - p = 10^{-kt} = e^{Kt}$$

and the third and the last terms can be transformed to Eq. 2b.

In most of the studies which have been made of this equation, L and L_t have been measured by the amount of oxygen removed from solution. For 20°C., k has been found to be 0.1.

Because of its importance this formula has been much studied. Phelps states (3): "There are no obvious reasons why a biochemical reaction of this sort should proceed in accordance with the monomolecular formula. The implication is that the metabolic activities of the bacteria proportion themselves exactly to the concentration of available organic matter remaining at any time."

Although the oxidation rate cannot be speeded with sewage alone, it can be made to operate at higher rates in the presence of activated sludge. Nor is it the presence of the oxidizable material in the sludge which accounts for the high rate of action. Numerous experiments (4) (5) (6) indicate that the sludge alone utilizes oxygen slowly, but when sewage is added the rate of oxygen utilization increases immediately and sharply, apparently a function of both the amount of seeding material present in the sludge and of the oxidizable material in the sewage.

Example of Case III

The example of Case III is the reaction resulting from the anaerobic digestion of sludge. A formula was developed by Fair and Moore (7). The present contribution is the assumption that one of the two constants in the formula is not a constant, but is a measure of the amount of seeding material present at the start. The fundamental Eq. 3a appears to have a logical basis. The term $(s + m\ p)$ is made up of s, the original seeding material per unit of food available, plus the amount of seeding material which has developed per unit of food destroyed, or a constant, m, times p. The term $(1 - p)$ represents the proportional part of the original food still available. The product of these two is a measure of the contacts between the two.

A parallel to this case and that of

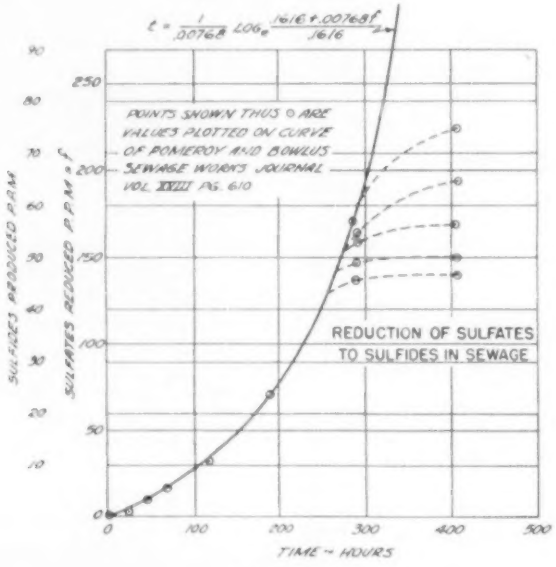

FIGURE 1.

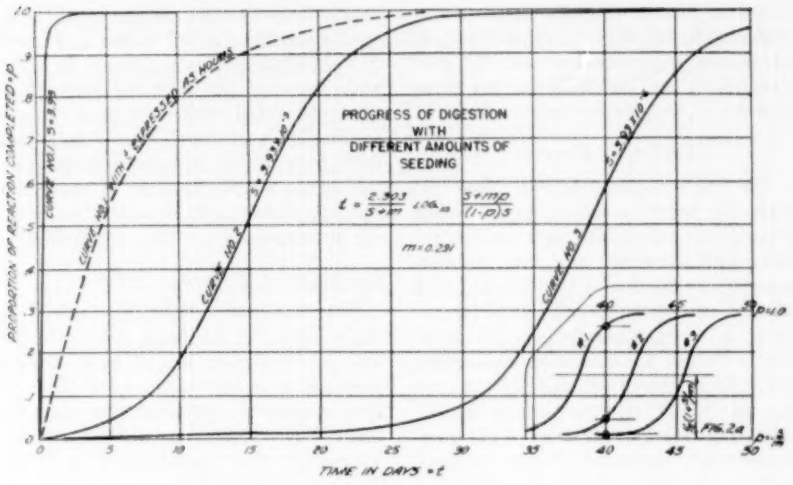

FIGURE 2.

Case I is possible with larger organisms. If mice were in a granary the increase in the number of mice could be by geometric progression and the corresponding destruction of food would follow the curve of Case I(Figure 1), including the abrupt halt when the food was nearly exhausted. If, however, the food were widely scattered over a large area, the rate of consumption of food per unit present would vary as the rate of contacts between the mice and the food supply, which would of course be a function of the concentration of mice $(s + m\ p)$ and of the concentration of the food $(1 - p)$.

The data submitted by Fair and Moore can be represented by

$$t = \frac{2.303}{0.00393 - 0.291} \times \log_{10} \frac{0.00393 - 0.291\ p}{(1 - p)0.00393} \qquad (8)$$

which is in the form of Eq. 3b and in which $s = 0.00393$, $m = 0.291$, and $k = 1$.

In Figure 2, Curve 2 shows the value of t plotted against p. Also given are curves showing this relationship with $s = 0.00000393$ and with $s = 3.93$. Curve 1, resulting from the small value of s, illustrates the process when raw sludge is left to digest with only the small amount of seed material which is available from the sludge itself. This occurs when the sludge digestion is first started in a new plant. Curve 2 is characteristic of most bottle digestion experiments. Curve 3 results when a large amount of seeding materials is present at the start. It represents the action which occurs when a small amount of sludge is added to a sludge digestion tank. Note that the resulting curve resembles the "Phelps" curve of Case II. Actually, Curve 3 is the same as Curves 1 and 2 to a different vertical scale and with the point of inflection submerged below the x-axis. Each of the three curves is symmetrical about a point of inflection and all approach asymptotes (upper, $p = 1.0$; lower, $p = s/m$). The three curves as shown are merely portions of the complete curve, which, if the distance between $p = 1.0$ and $p = -s/m$ were made the same, would be similar, although in different positions with regard to t. The similarity and

relationship between the three curves is shown in the insert (Figure 2a), in which the distances between the two asymptotes are the same for all three curves.

Effect of Process

The previous discussion is concerned with the reaction which occurs when a quantity of food is brought in contact with seed material, and the residual quantity of food and the original and formed amount of seed material remain in contact throughout the reaction. This is the condition that exists not only in the experiments cited, but also in B.O.D. determinations, in the self-purification of streams, in the compressed air activated sludge process, and in secondary sludge digestion.

A second process is with food material added continuously or at regular intervals to a container of fixed volume, and thoroughly mixed up with all the material in the process while an equal volume is displaced, the displaced material being in the same state of reaction as exists with the contents in the container. This is the process of mechanical aeration tanks, and of primary sludge digestion tanks, especially those with stirring devices or with recirculation pumps. Both of the above processes also are present in a single digestion tank where the upper level is stirred up by gas formation and the bottom level is thick and quiescent.

Still a third process is where the seeding material stays in the process and the food moves by it. This ideal condition occurs in trickling filters and may be partially responsible for the rapid purification achieved by this process.

Sludge Digestion Tanks

In the digestion of sludge, raw sludge is added either intermittently or constantly and mixed with a comparatively large volume of digesting sludge. Mixing is essential, as the added raw sludge contains little seeding material and if unmixed the process would proceed along the lines of Curve 1 (Figure 2). The mixing is produced by stirring, by pumping, or by convection currents, aided by the action of the gas produced in the process. After this first stage the sludge passes to the second stage where, because of quiescent conditions and high viscosity, the process as expressed by Eqs. 3 prevails.

Formula for Primary Digestion

For a primary digestion tank V is the volume of the tank, and v is the volume of sludge added and leaving the tank in a unit of time t. The volume v entering the sludge contains n units of raw sludge per unit of volume. Therefore, V/v is equivalent to T, the displacement period.

Let it be assumed that raw sludge with a negligible amount of seed material is added continuously and mixed practically instantaneously with the content of the tank. Because of this the sludge removed contains the same ratio of seed material and food (undigested sludge) as exists throughout the tank. Let $100\ (1-p)$ equal the percentage of undigested digestible material both in the tank itself and in the sludge leaving the process. The quantity $100\ p$ equals the percentage of total digestion accomplished by the tank.

Therefore, from each unit of raw sludge added to the tank there results $1-p$ units of undigested sludge and $m\ p$ units of seed material. Let it also be assumed that the rate of gas production, dG/dt, is a measure of the rate at which food is being changed to seed material. Therefore, because the digestion in each unit of food proceeds at the rate determined by the product of seed material and the food existing in the mixture,

$$dG/dt = k\ n\ V\ m\ p\ (1-p) \quad (9)$$

However, the rate of food destroyed, or gas produced, is also equal to the difference in the rate at which food is

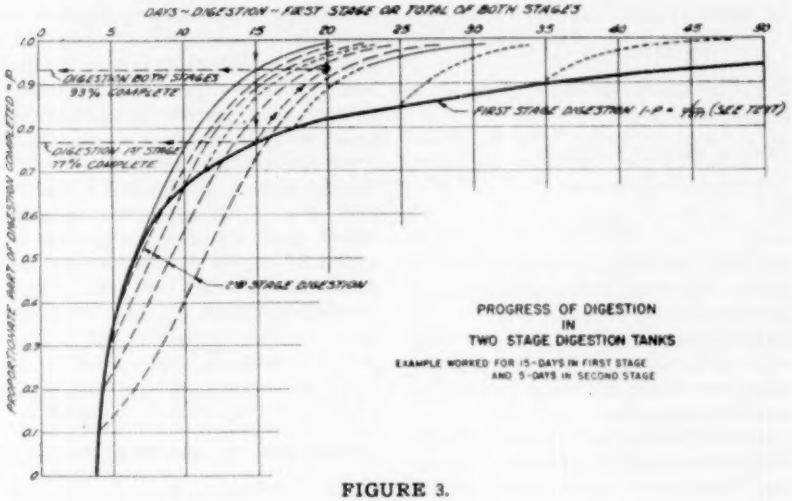

FIGURE 3.

added to, and the rate at which it leaves the tank, or

$$dG/dt = v\ n - v\ n\ (1-p)$$
$$= v\ n\ p \quad (10)$$

Because Eqs. 9 and 10 must be equal,

$$1 = K\ T\ m\ (1-p) \quad (11a)$$

or

$$(1-p) = \frac{1}{K\ T\ m} \quad (11b)$$

The plot of $(1-p)$ against T is an equilateral hyperbola. In Figure 3 this curve is plotted with a value of $K\ m = 0.291$, as taken from Eqs. 3. Thus,

$$(1-p) = 1/0.291T \quad (12)$$

When T is less than $\frac{1}{K\ m}$, the value of p in the expression $1-p$ exceeds unity, which is not possible. When T is less than $\frac{1}{K\ m}$, the rate of formation of seed material is less than the rate at which it leaves the tank, so no seed material is present and, theoretically at least, there is no digestion.

Figure for Two-Stage Digestion

In the secondary sludge digestion tank the process proceeds according to Eqs. 3. Using $m = 0.291$ and $s = 0.291p$, curves for Eq. 3b are drawn from various points on the curve $1-p = \frac{1}{K\ T\ m}$. These broken-line curves (Figure 3) represent the secondary sludge digestion. Thus, the total percentage of digestion accomplished can be obtained by taking the point on the solid line opposite the time in the primary stage and following the dotted line of the secondary stage to the total digestion time. To obtain the actual time the sludge is in the secondary digestion tank it is necessary to have not only the record of sludge added and sludge and supernatant liquor removed, but also to know the history of the separation of the supernatant liquor from the sludge, which latter is not ordinarily available.

The maximum total reduction of $1-p$ (or the maximum increase of p) is obtained by keeping the process in the first stage until the rate of reduction is equal to that of the second stage for the same value of $1-p$ or p. Differentiating both sides of Eq. 11,

$$-K\ m\ dp = \frac{-1}{T^2}\ dt = -(1-p)^2\ k^2\ m^2\ dt$$

Therefore,

$$dp/dt = k\,m\,(1-p)^2$$

Equating this to the value of dp/dt in Eq. 3a,

$$dp/dt\ K\ (m\,p)\ (1-p) = K\ m\ (1-p)^2$$

or

$$p = \tfrac{1}{2}$$

Consequently, the maximum reduction is obtained when action proceeds one-half of the way to completion in the primary stage of the digestion. With $m = 0.291$, the time in the primary stage that would theoretically produce maximum digestion is 6.9 days.

As the two states or stages of perfectly mixed and of quiescence contact are undoubtedly approached at the start and finish of the process in digestion tanks, there must be a tank volume and a corresponding period of time in between, during which a more or less incomplete mixing takes place. Referring to Figure 3, under actual conditions the curve of the digestion process would follow up the heavy curve of the first stage for a while, leave it at a tangent, slope away from the curve reverse with a slightly S-shape and finally become tangent to a curve of the second stage.

It is, of course, apparent that mixing is essential at the start, as otherwise the digestion process would follow the slow rate of a self-seeded process as illustrated by Curve 3, Figure 2. This mixing, however, produces a short circuiting that carries undigested material out of the stage. The conclusion from the above discussion and from an examination of Figure 3 is that for best results mixing should be maintained until the digestion process has gone half way to completion, and that after that the more quiescent the material the better the results. The maximum possible digestion for a given period of time is represented by the heavy and light solid lines forming the left limits of the curves of Figure 3.

Relationship of the Basic Formulas

The relationship between the three basic formulas is that the differential of Case III contains two terms, one each of which occurs in Cases I and II, the other term being a constant. However, if curves for the actions that occur were extended it would be seen that Cases I and II are really skew versions of Case III. This is illustrated in Figure 4. Figure 4a shows the curves as for the formula herein derived; Figure 4b shows the curves of the action as it actually occurs. The relationship is more apparent if the derivative dp/dt is plotted against p, starting with $s = 0$. Figures 4c and

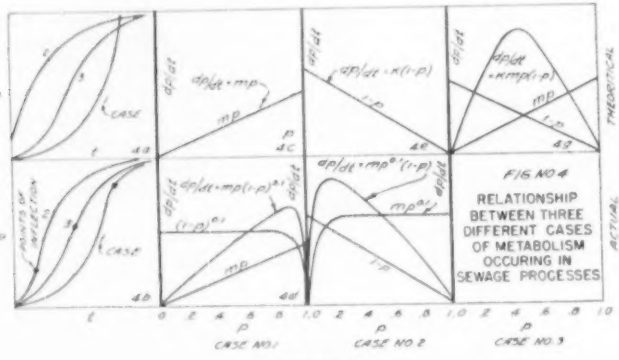

FIGURE 4.

4e show the relationship as herein given, whereas Figure 4d and 4f show the true relationship. For Case III (Figure 4g) there is no discrepancy between the formulas given herein and the results of tests.

If Eqs. 1a and 2a are to be correct over their entire range they should contain a second term that is a constant or nearly a constant over much of the range in values of p, but which drops or rises from zero very sharply. The three formulas could all be represented by

$$dp - n\ p^a\ (1 - p)^b\ dt$$

in which the following number (0.1) represents the order of magnitude (but not the actual values) of a and b where not equal to unity.

	Actual Curves		Theoretical Curves	
	a	b	a	b
Case I	1	0.1	1	0
Case II	0.1	1	0	1
Case III	1	1	1	1

This is only one of a number of ways in which the direct and indirect relation between the rate of the action and the amount of seed material and of food present could be represented.

Discussion

The number of equations whose curves would fairly represent an orderly set of data is unlimited and a good fit is not necessarily proof of the validity of the formula. It may be asked if such a simple set of formulas as herein presented actually represents the complicated and involved relationship which must exist in a bacterial jungle such as a sludge digestion tank. Perhaps it could. In spite of the complexity there must be a certain bottleneck action which controls or places a ceiling on the rate of the total action, and this control may have the simple relationship to the total action as herein given. Probably a more serious objection would be that different processes would take over the control at various stages of the total process and the resulting formula is an over-all approximation of the results from a series of controlling actions.

From a practical standpoint, a formula which would give the relationship between the variables within reasonably close limits could be used as a basis for practical conclusions.

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DUAL GARBAGE AND SEWAGE DISPOSAL PROJECT FOR SAGINAW, MICH.*

By George E. Hubbell

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The City of Saginaw, Mich., is sewered on the combined plan, the sewage from a present estimated population of 92,000 being discharged without treatment from 28 sewers, the outlets of which are located along each side of the Saginaw River. Because many of the sewers are below flood river stage, the problem of collecting the sewage involves storm water pumping during periods of high river level. In addition to the collection and treatment of the sewage, the city desired to provide for the disposal of garbage at the sewage disposal site, as an integral part of the sewage treatment process, if such inclusion was feasible and economical.

The Saginaw River divides the 10,437-acre area of the city into an East Side section having an area of 5,634 acres, and West Side section of 4,803 acres (see Figure 1). The Saginaw River drainage basin above the city has an area of 6,200 sq. mi. The average daily stream flow is estimated at 1,000 c.f.s. with minimum daily flow of 500 c.f.s. Flood flows of 62,000 c.f.s. have been observed.

During the period 1904 to 1946 inclusive, the flood stage at Genesee St. exceeded Elev. 585.0 some 34 times, the maximum recorded elevation of 591.26 occurring in 1904. The majority of the sewer outlets discharge at invert elevations varying from 580.0 to 583.0. Approximately 10 per cent of the residents live within areas below flood stage. Study of the daily flood-stage records indicated that flood stages can exist for periods up to two weeks, during which time rainfall producing runoff occurs. Flood stages of the Saginaw River have all occurred during the months of March, April, and May. During these same months, rainfall intensities are approximately 50 per cent of those occurring during July. Accordingly, the formula

$$I = \frac{87.5}{t + 25}$$

—in which I is the rainfall intensity in inches per hour and t is the time of concentration in minutes—was adopted as the design basis for storm water runoff during the months of flood stage. Flood pumping capacity is to be provided as follows:

Location	Unit Flow (c.f.s./acre)	Area (acres)	Total Flow (c.f.s.)
East Side	0.27	5,185	1,400
West Side[1]	0.36	3,015	1,100
Average	0.30	8,200	2,500

[1] Weiss St. drainage from 2,000 acres to discharge directly to the Saginaw River by gravity.

Tunnel Interceptors

In order to collect the sewage from the various outlets, a tunnel interceptor will extend along each side of the river. The West Side interceptor crosses the river at Weiss Street to join the East Side interceptor, which continues to the treatment plant at the northeast limits of the city. All sewage flow to the interceptor will be con-

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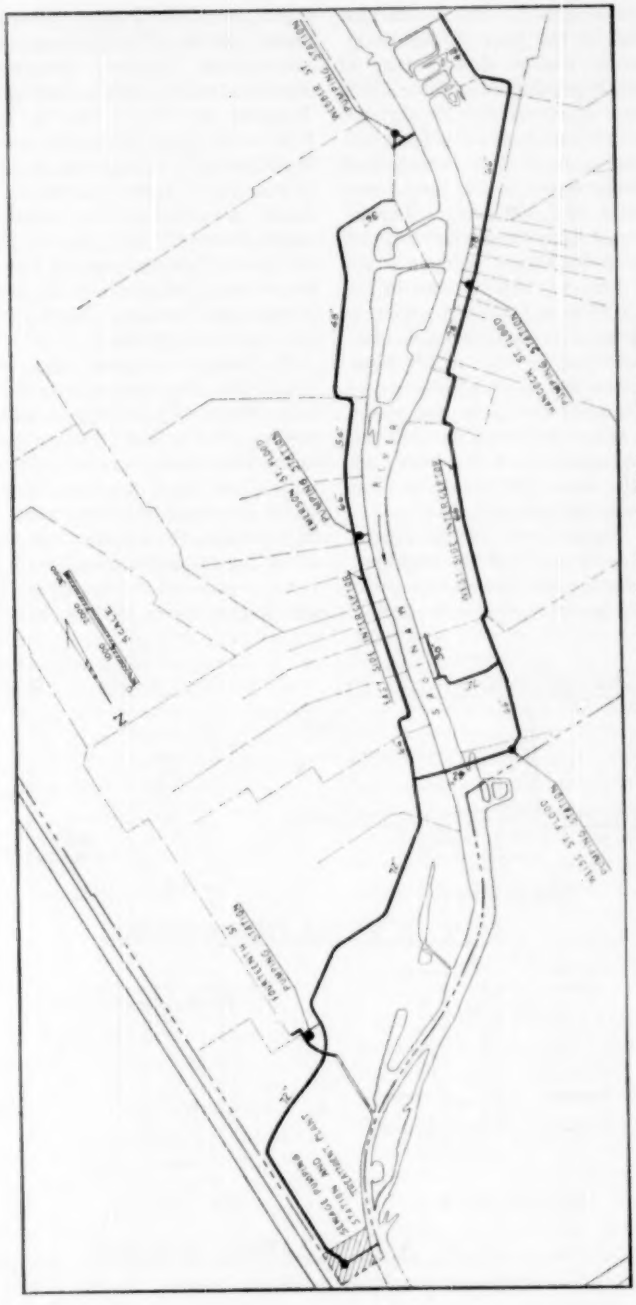

FIGURE 1.—General plan of proposed collecting and interceptor sewer.

trolled and regulated. The interceptor is designed on the basis of the maximum hourly sewage flow being 80 c.f.s. (160,000 population at 324 g.c.d.), the protective storm flow being 160 c.f.s. (160,000 population at 648 g.c.d.) and the storm water flow during flood periods being equal to the storm system capacity of 2,500 c.f.s. Regulation of sewage flow into the interceptors will be from the depth of flow in the combined sewers. Storm flows in excess of 0.5 c.f.s. per 1,000 population will discharge directly to the river during normal river levels. Each regulator chamber has an overflow weir set at approximately the hydraulic gradient of the sewer to permit passing full storm flow capacity of the sewer directly to the river without storm overflow into the interceptor.

During flood river levels, storm flows will discharge over the regulator chamber weirs into the intercepting system. Backwater gates will prevent discharge of flood river water into the sewer system. Flood pumping stations located at Webber, Emerson, and Fourteenth Sts. on the East Side, and Hancock and Weiss Sts. on the West Side, will pump from the interceptor system, which will operate at hydraulic gradients, independent of the invert grade, of sufficient slope to convey the storm water laterally to the pumping stations. The intercepting sewers thus serve the dual purpose of collecting sewage and carrying storm flows during flood river levels.

Regulator chambers have been divided into two general classifications (see Figure 2). Type A chambers, serving sewers over 30 in. in diameter, are provided with a standard regulator and sluice gate, together with backwater gate and overflow weirs. Type B chambers, for sewers from 12 in. to 30 in. in diameter, are provided with a sluice gate for regulation of the sewage flow, together with overflow weirs

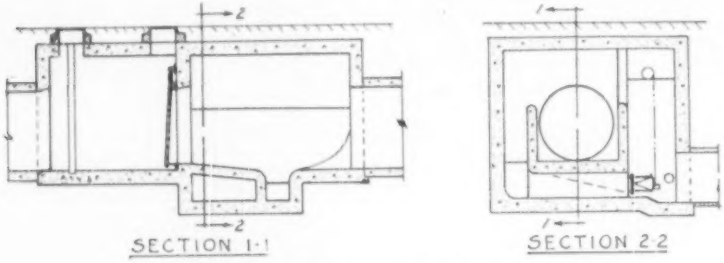

FIGURE 2.—Regulator chamber details.

and backwater gate. Particular care was used in the location of each regulator chamber to permit construction with a minimum interference with auto and rail traffic.

The interceptor system consists of tunnel sewers ranging from 48 to 78 in. in diameter. During periods of maximum runoff under flood conditions, maximum velocities of 12 f.p.s. will occur in the tunnel sections adjacent to the flood pumping stations. The tunnels are approximately 40 ft. below ground level, located in blue clay suitable for tunnel construction. A gravity crossing beneath the Saginaw River, use of steep gradients during flood periods, and good construction conditions were considerations in fixing the tunnel depths.

The river crossing consists of 42-in. concrete pipe having an 8-in. wall thickness and rubber gasketed metal joints with two 1⅝-in. tie bolts at each joint. Directly under the river proper, the foundation is sand and gravel; for approximately 1,000 ft. west of the river bank, the foundation is soft, wet, gray silt requiring wood pile support and steel sheeting during construction.

Principal quantities of tunnel interceptor construction are as follows:

Diameter (in.)	Length (ft.)
48	5,000
54	1,900
66	17,300
72	16,500
78	3,700

Pumping Stations

Storm water and flood pumping stations are of circular caisson type construction. Two stations are located on the West Side; one at Hancock St. with eight gasoline engine-driven pumps, and one at Weiss St. with three electric-driven pumps. On the East Side, there is a station at Webber St. with three electric-driven pumps; one at Emerson St. with six gasoline engine-driven pumps; and one at Fourteenth St. with three electric-driven pumps. All pumps are similar, each having a capacity of 100 c.f.s., those at Webber St. and Fourteenth St. to operate at 15-ft. head, and the remainder at 28-ft. head. The pumps are of the vertical propellor type, operating at 490 r.p.m. without suction or discharge valves, and each equipped with a backwater gate on the outlet. The pumping units hang in wet wells, which are maintained in a dry state during periods of normal flow in the interceptor system. The wet wells are sealed from the interceptor by means of tide gates. Each station is equipped with bar screens having 3-in. clear openings. All discharge backwater gates are above normal river levels to permit ready inspection.

The choice of gasoline-driven pumping equipment for 14 of the units was based on the desire to be independent of power failure at the Hancock St. and Emerson St. stations, as these stations are strictly flood pumping stations. In addition, their infrequent operation places them in a very undesirable position so far as power rates are concerned. The Webber St. and Fourteenth St. stations are storm water pumping stations required to pump low-level areas during periods of storm water runoff, and will be automatic in operation. The Weiss St. station is to be equipped with electric motor-driven pumps to provide for automatic dewatering of the interceptor system during periods of storm spill into the system.

The Webber St. and Fourteenth St. pumping stations each have three 200-hp., 440-v. induction motors; the Weiss St. station, three 350-hp., 440-v. induction motors. Across-the-line dead-front starting equipment is used in each station. The gasoline engines in the Hancock St. and Emerson St. pumping stations are to deliver 430 hp. at 1,200 r.p.m., and drive the vertical pumps through right-angle drive

units capable of transmitting 400 hp. at a speed reduction ratio of 1: 2.4.

Garbage Collection and Disposal

Prior to the inclusion of garbage disposal as a part of the sewage treatment plant, a study was made of various methods of handling and disposing of the garbage at the treatment plant.

Saginaw maintains city-owned or leased dumps and provides collection of ashes during the winter months. In addition, rubbish collected during the spring cleanup and debris from street cleanup operations are disposed of by the city. Private individuals and collectors of rubbish also use the city dump areas. Of the 23,000 homes in Saginaw, about 7,000 in winter and 10,000 in summer use the services of seven licensed private garbage collectors. About 60 to 70 per cent of the homes are without regular garbage collection service.

To provide for uniform collection service and adequate sanitary disposal of the garbage, the city plans to ultimately provide garbage collection as a city function with disposal of the garbage by incineration. Garbage and rubbish will be collected separately, using standard collection equipment. Garbage will be received at the treatment plant, and dumped into a receiving hopper located within the garbage-handling room (see Figure 3). From the hopper, the garbage is elevated on a pan conveyor for hand sorting and

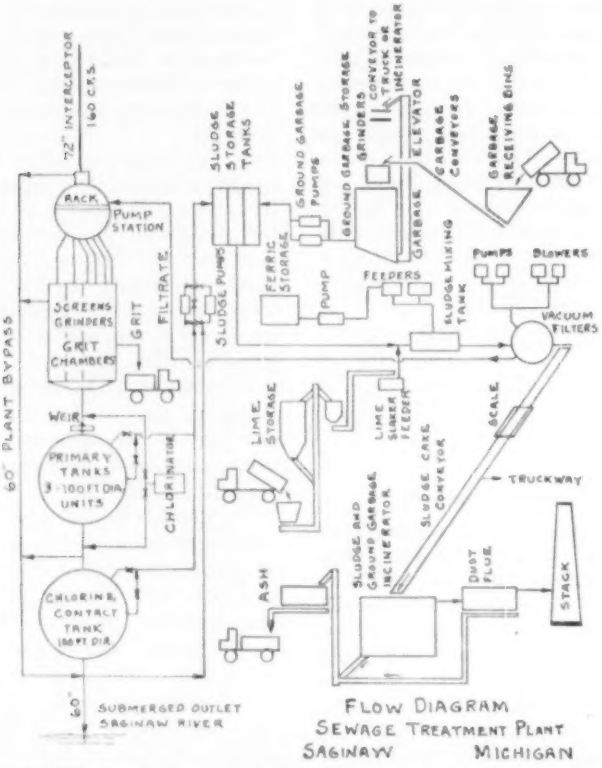

FIGURE 3.—Sewage and garbage treatment plant flow diagram.

inspection prior to discharge into dry-type grinders. The ground garbage is discharged into dual receiving tanks, from which it can be either pumped or mechanically elevated to a belt conveyor. If pumped, the garbage goes to storage and decanting tanks, where it is mixed with the raw sewage solids for dewatering on vacuum filters and incineration. If elevated to the belt, it can be fed directly to the incinerator; or solid materials such as bone, glass, etc., can be discharged directly to trucks for disposal on fill areas.

The foregoing direct method of disposal was adopted only after a thorough study of the economics of the digestion of the garbage solids with the sewage solids. The types of combined sewage and garbage solids disposal units considered were: (a) filtration and incineration; (b) digestion, filtration, and incineration; and (c) digestion, filtration, and sludge beds.

Comparative cost studies were made, not including the cost of garbage collection or the cost of operating the garbage handling building. Interest on capital expenditures was computed at 2.5 per cent, and depreciation was based on the estimated life of the construction on an annuity basis at 2 per cent interest rate. Equipment sizes were proportioned to provide the equivalent of two-shift operation, so that salaries and wages for operation of the various systems remained the same. The cost of chemicals varies directly with the solids load, and was so evaluated. Credit for excess gas available for pumping sewage and building heating was allowed for under plans (b) and (c). Digester capacity was computed on the basis of 30 cu. ft. per pound of volatile solids added daily during the maximum month. Sand beds for sludge drying were estimated at 6 acres. Green, wet garbage was estimated at 0.6 lb. per capita per day at 82 per cent moisture, with total sewage and garbage dry solids removal and requiring treatment during the maximum month (September) equal to 0.33 lb. per capita per day, with an average

	Sewage Only; Filtration and Incineration	Sewage and Garbage		Digestion and Sludge Beds
		Filtration and Incineration	Digestion, Filtration, and Incineration	
Plant load (tons)[1,2]	17,236	30,417	30,417	30,417
Sludge cake (tons)[1]	10,650	20,988	11,166	—
Wet sludge (cu.yd.)[1]	—	—	—	48,924
Dried sludge (cu.yd.)[1]	—	—	—	9,785
Incinerator capacity (tons per day)[3]	39	77	41	—
Construction cost	$238,000	$264,000	$926,000	$959,000
Annual oper. cost	30,900	42,700	28,700	15,900
Interest and deprec.	12,000	13,400	42,900	42,400
Total annual cost	$ 42,900	$ 56,100	$ 71,600	$ 58,300
Cost per ton-plant load 82% moist basis	—	$1.84	$2.35	$1.92

[1] Annually.
[2] 82 per cent moist basis.
[3] Based on maximum month.

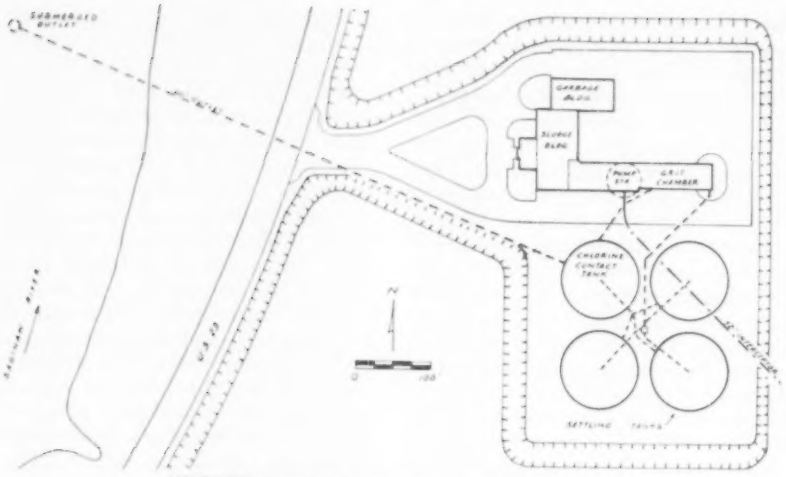

FIGURE 4.—General site plan of treatment plant.

volatile content of 72 per cent. Estimates were made for a connected population of 120,000.

Based in part on the foregoing, an economic analysis (see p. 179) showed that the net cost of disposal of wet, green garbage by filtration and incineration should be estimated at $1.00 per ton.

As a result of the analysis and after inspection of various existing sewage plants, the City Council ordered the inclusion of garbage disposal facilities in the design of the sewage treatment plant. On the basis of minimum costs, simplicity of operation, and elimination of digester overflow problems with attendant decrease in plant efficiency, the direct method of filtration and incineration of solids was adopted.

Description of Treatment Plant

The sewage plant is located on a 14-acre site (Figure 4) at the northeast corner of the city. Saginaw River elevations at the point of sewage discharge are: low month, Elev. 577.0; mean, Elev. 580.25; and 1904 flood, Elev. 588.7.

The plant is to be located on the east side of the site, where there is an excellent clay formation. The first floor will be set at Elev. 592.0, above flood level, with basement floor at Elev. 578.0. As the existing site is at Elev. 581.5, the plant will be constructed with a minimum of excavation. The general plant site will be filled to Elev. 590.0.

The plant is of the primary treatment type, with chlorination of the effluent. A flow diagram is given in Figure 3. All plant units have been designed for a population of 160,000 except the settling tanks and the sludge and garbage equipment, which have been designed for 120,000 population. The expected sewage flows are as shown in Table I.

Sewage reaches the plant through a 72-in. interceptor with invert at Elev. 541.7, and passes through a bar screen having 3-in. clear openings. Synchronous motor-driven pumps (two at 15 c.f.s., two at 42.5 c.f.s., and one each at 20 and 25 c.f.s.; total, 160 c.f.s.) discharge to the grit chambers at overflow Elev. 594.5.

The pumping station, of the circular caisson type with 44-ft. inside diameter by 59.5-ft. maximum depth, is provided with motor-operated shutoff gates, surge riser, and overflow bypass.

TABLE I.—Design Sewage Flows for Saginaw, Mich., Project

Type of Flow	Flow per 1,000 (c.f.s.)	Total Flow			
		120,000 Pop.		160,000 Pop.	
		(c.f.s.)	(m.g.d.)	(c.f.s.)	(m.g.d.)
Aver. yearly	0.20	24.0	15.5	32.0	20.7
Max. daily	0.32	38.4	24.8	51.3	33.2
Max. hour	0.50	60.0	38.8	80.0	51.8
Min. day	0.14	16.8	10.8	22.4	14.5

Positive wet-well ventilation is provided by a 4,000-c.f.m. blower discharging fresh air into the well.

Four grit chambers, each equipped with a mechanically-cleaned bar screen having 1-in. clear openings, together with four screenings grinders each having a capacity of 1,100 lb. per hour, provide for grit removal and screenings treatment. Control of the grit chamber is by means of motor-operated gate valves. The design velocity is 0.68 f.p.s. with 1.5-min. detention. Grit removal is by means of V-bucket scrapers with elevation of the grit to overhead storage hoppers for screw conveyor discharge to trucks. From the grit chamber, the sewage flows through a 60-in. concrete pipe to a central distribution weir chamber, where a four-unit sharp-crested weir divides the flow to the settling tanks.

Three primary settling tanks, each 100 ft. in diameter and having a side water depth of 11 ft. 10 in., with water surface at Elev. 591.5, are fed from the weir chamber through submerged influent conduits 2 ft. 6 in. square. At the center of each tank the flow is directed vertically by means of a baffle, which divides the 36-in. riser into four compartments. Above the riser is a series of five horizontal plate orifices ranging in opening diameter from 35 in. to 20 in., and spaced over a vertical height of 8 ft. Surrounding the inlet at a diameter of 14 ft. is a series of adjustable diffuser vanes, which in the tangential position provide a complete closure, but which may be opened as required to provide for optimum settling conditions. The inlet structure is an integral part of the support for the sludge removal mechanism. The effective volume of each tank, not including the cone, is 700,000 gal., providing a total volume of 2,100,000 gal.; total tank surface is 23,550 sq. ft.; and total weir length, 942 ft. For the average yearly flow of 15.5 m.g.d. the settling tanks provide a nominal detention period of 3.25 hr., a settling rate of 658 g.p.d. per sq. ft., and an overflow rate of 16,500 g.p.d. per ft. of weir; for the maximum pump capacity provided the values are respectively, 0.49 hr., 4,400 g.p.d. per sq. ft., and 110,000 g.p.d. per ft.

From the settling tank, the sewage flows to a chlorine contact tank 100 ft. in diameter, with side water depth of 9 ft. 10 in. This 650,000-gal. tank is equipped with sludge removal equipment and an inlet similar to the primary tank inlets. Water surface is at Elev. 589.0, with feed through a 4- by 5-ft. submerged influent conduit. For a 15.5-m.g.d. flow the chlorine contact tank provides a nominal detention period of 60 min., which, at a 4,000-lb. per day rate makes the maximum available dose 31.0 p.p.m.

Model studies of circular tanks equipped with the horizontal orifice type inlet and diffuser vanes, indicate that approximately 5 per cent of the flow is retained for less than 43 per cent of the nominal detention time. Thus, at the 15.5 m.g.d. rate, 5 per cent of the flow will be detained for less

than 26 min.; 36 per cent will be retained from 26 to 52 min.; 28 per cent from 52 to 78 min.; 17 per cent from 78 to 104 min.; 9 per cent from 104 to 130 min.; and the remaining 5 per cent from 130 to 180 min.

The plant outlet consists of 563 ft. of 60-in. reinforced concrete pipe, with each 12-ft length supported on four wood piles. At the river bank, a stop log chamber is provided at the outlet transition to 60-in. lined and coated ⅞-in. thick steel pipe, which extends below river bottom to a submerged circular diffuser outlet crib. The top of the crib is set 22.5 ft. below the U. S. Lake Survey low water datum, and is designed to prevent damage due to dragging anchors. The outlet has an 8-ft. diameter cap set 1 ft. above the deck and provides for mixing of the sewage flow with the river flow.

Two 150-g.p.m. plunger-type sludge pumps provide for discharging sludge from the settling tanks to three 4,000-cu. ft. sludge storage tanks used for decanting and thickening the sludge prior to filtration. One tank is equipped with a bucket sludge elevator having a variable capacity from 18 to 280 g.p.m. for feeding the sludge filters. All sludge piping is 6-in. diameter cast iron, and provision is made for backflushing all lines with settled sewage and for direct pumping to the filters or to tank trucks.

Sludge dewatering equipment consists of two 250-sq. ft. vacuum filters. Provision is made for two additional filters.

Sludge cake is discharged on to a horizontal belt 24 in. wide, operating at a speed of 75 ft. per min., that discharges either to the incinerator or to a truckway hopper. Total 24-hr. output of the two filters is 86 tons of sludge cake based on 5 lb. of dry solids per square foot per hour at 65 per cent moisture. The estimated required maximum month output for a tributary population of 120,000 is 77 tons per day.

Sludge will be incinerated in one 6-hearth unit having an outside diameter of 20 ft. 9 in. and capable of burning sewage sludge cake containing ground raw garbage at a continuous rate of 120 tons per 24 hr. Provision is made for direct discharge of ground garbage to the incinerator. Combustion gases from the incinerator pass through a dust flue with dust removal conveyor, and thence to a 110-ft., high temperature, brick stack. Ash is fed through an elevator and screw conveyor to a storage bin having a capacity of 500 cu. ft., from which an 18-in. screw conveyor discharges to the truckway. A 12,000-gal. underground oil storage tank provides for building and incinerator oil requirements. All oil-burning equipment is designed for handling No. 5 fuel oil.

The garbage handling equipment consists of two garbage receiving hoppers of 1,560 cu. ft. capacity; two garbage pan conveyors 4 ft. wide with speeds from 5 to 30 ft. per min. for elevating the garbage from the receiving hopper to the grinders (material that will damage the grinders is sorted on the conveyor and placed in cans for removal by trolley hoist to trucks); two rotary-knife-type dry grinders, each having a capacity of 6 tons of green garbage per hour; two ground garbage storage tanks, each of 6,000 cu. ft. capacity and hopper-bottomed, with removal of ground garbage by gravity drains to the pumping station, pump, or bucket elevator; two centrifugal ground garbage pumps, each having a capacity of 130 g.p.m.; two vertical dewatering bucket elevators for discharge direct to garbage conveyor belt; garbage conveyor belt for discharge of ground garbage direct to incinerator, or for discharge of ground glass, bones, etc., to trucks in the truckway.

Equipment for handling the various chemicals is as follows:

Lime.—Truck discharge of pebble lime into a truckway hopper with a 9-in. conveyor having a capacity of 20 tons per hr., to elevate the lime to a 50-ton storage bin. The conveyor also discharges from the storage bin to an auxiliary hopper feeding a 5-in. conveyor serving the lime slaker. A belt-type automatic feeder and 500-lb. per hr. slaker discharge into the sludge mixing tank.

Ferric Chloride.—Storage is provided in a 10,000-gal. rubber-lined steel tank located in the basement. Two 20-g.p.m. pumps discharge into two volumetric feeders, each of 200-gal. capacity, which in turn feed into the sludge mixing tank.

Chlorine.—Automatic proportionate feed control equipment with two chlorinators, each having a capacity of from 400 to 2,000 lb. of chlorine per 24 hr., is served by two recording scales and overhead hoist equipment for handling ton containers.

The plant water supply consists of a domestic supply extended from the city system and serving all drinking fountains, lavatories, toilets, and hot water system and a separate industrial system. The industrial system receives its supply through an air-break gravity tank, from which it is repumped to a pressure storage tank serving all sewage equipment, hose outlets, flushing connections, and the chlorinators.

The plant heating system consists of two low-pressure oil-fired boilers, each rated at 4,340 sq. ft. of radiation. The office, laboratory, and pump room are heated with cast iron radiation, the plant proper being heated with unit heaters. Power ventilators are installed in the garbage receiving and grinding rooms, as well as in the incinerator enclosure.

Primary electric service (at 22,000 v.) is obtained from the local power company. A 1,500-kva. transformer located on the grit chamber deck supplies 2,400 v. for the synchronous motor-driven sewage pumps. The plant power supply is stepped down to 440 v. through a 300-kva. transformer, with individual 110-v. lighting transformers spaced throughout the plant.

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The work of preparing the plans for this project was aided to a considerable degree by the excellent base maps, records, and surveys furnished by the City of Saginaw through Hugh Benner, Director of Public Works.

EFFICIENCY STUDY OF A RECIRCULATING SEWAGE FILTER AT CENTRALIA, MO.

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A study of various methods of operating the Centralia, Mo., sewage treatment plant, having a small, shallow trickling filter, was made with the aid of a U. S. Public Health Service trailer laboratory. The design of the plant permitted operation both without recirculation and with recirculation to the primary tank influent of either final effluent, filter effluent, or final clarifier underflow (tank liquor withdrawn from the sludge pipe). The information and results of this study are presented here.

The overdesigned Centralia plant treats predominantly domestic sewage. The plant was designed as a two-stage biofiltration plant, but only one trickling filter was completed. Sewage enters the plant by gravity and, after passing through the grit chamber and comminutor, flows to the primary clarifier. The settled sewage flows by gravity to a wet well and is intermittently lifted by a float-controlled centrifugal pump to the rotary distributor of the 3-ft. deep trickling filter. The filter effluent flows by gravity to the final settling tank, and finally to a ditch. Recirculated flows are returned by gravity to the plant influent. Except in study period IV, sludge from the primary tank and from the final settling tank was pumped to the digester daily, the digester supernatant being automatically displaced and returned to the grit chamber ahead of the comminutor.

Settling Tank Characteristics

Preliminary to the study, tests were made on the flowing-through period of the settling tanks under conditions of no recirculated flow by adding 25 gal. of sewage containing 30 lb. of dissolved salt to the plant influent. Samples of effluent were collected frequently and titrated for chlorides. The results of the study of the settling tank characteristics are summarized in Table I.

Due to the low flow and the lack of recirculation, the theoretical detention periods were very long (8 to 15 hr.)

TABLE I.—Clarifier Hydraulics, Centralia, Mo., Sewage Treatment Plant

Characteristic	Primary Clarifier	Final Clarifier
Vertical overflow rate (g.p.d./sq.ft.)	105	145
Weir overflow rate (g.p.d./ft.)	89	104
Theoretical detention (hr.)	15.0	8.4
Flow-through period[1] (hr.)	8.7	3.8
$\frac{\text{Flow-through period}}{\text{Theoretical detention}}$	0.58	0.45
Peak salt discharge (mode)(hr.)	7.0	3.5
Volumetric efficiency[2] (%)	45	42

[1] By salt test.

[2] Taken as $\frac{\text{minutes to pass 10 per cent of salt}}{\text{minutes to pass 90 per cent of salt}} \times 100$.

and the overflow rates were unusually low (90 to 105 g.p.d. per foot of weir length). The flow of sewage to the primary tank was continuous, but the flow to the final tank was discontinuous due to the intermittent operation of the pump feeding the rotary distributor of the filter. In each 10- to 15-min. interval the distributor was in operation about one-half the time. The flowing-through period of the settling tanks was found to be about one-half of the theoretical detention period.

Filter Distribution Tests

During the course of the investigation, pan tests for sewage distribution

TABLE II.—Rotary Filter Distribution Data

	Centralia, Mo.		Elizabethtown, Ky.	Neosho, Mo.
Flow rate (g.p.m.)	168	452	650	1,200
Dosing rate (g.p.m./sq.ft.)	0.18	0.50	0.52	0.40
Coefficient of area	0.97	0.97	1.0	0.93
Coefficient of distribution	1.76	1.96	1.56	1.68
Dosing ratio	1.56	1.68	1.62	1.54
Mean depth ($\frac{1}{16}$ in.)	20.8	15.5	19.4	25.3
Standard deviation ($\frac{1}{16}$ in.)	8.80	6.80	6.44	10.5
Coefficient of variation	42.3	43.9	33.2	41.5

on the filter were made at two different rates of flow to the distributor. In one case, the variable speed drive on the pump was set so that the flow was just enough to start the distributor rotating; in the other, the pump was speeded up to the limit of the variable speed drive. The rates of pumpage were 170 and 450 g.p.m., respectively. The distribution tests were made in the same way as described in the sewage filter study at Elizabethtown, Ky. (1), so that the results can be compared (Table II) with the results of tests on the rotary distributors at Elizabethtown, Ky. (1), and Neosho, Mo. (2).

It may be noted that the coefficients of distribution and the dosing ratios at Centralia compared favorably with those criteria given for most of the plants studied by Walton (3).

Experimental Operation and Data

The experimental operation of the plant was divided into four periods of one week each. Samples and flow readings were taken Monday through Friday for each period. The source of recirculated flow was then altered, and Saturday and Sunday were allowed for the filter to become adjusted before sampling. The method of operation during each of the four periods is shown diagrammatically in Figure 1; dates and other pertinent data are given in Table III.

The average flow of sewage and recirculated liquor was computed from the weir readings taken at the time of sampling—every 30 min. from 8:00 A.M. to 12:00 midnight each day. Daily recorder values were used to compute the detention and overflow rates of the primary and secondary settling tanks.

The 32 half-hour samples of raw sewage, primary effluent, filter effluent, final effluent, and recirculated liquor were each composited in proportion to the flow, stored in an ice-box and analyzed the following day. Morning samples of raw sewage, primary effluent, filter influent, filter effluent, and morning and afternoon samples of final effluent were analyzed for dissolved oxygen immediately on collection. The location of sampling points for raw sewage, primary effluent, filter effluent, and final effluent are shown in Figure 1 as Points 1, 2, 3, and 4.

Standard analytical procedures (4) were employed. The copper sulfate-sulfamic acid method (5) was used for the determination of dissolved oxygen.

The pertinent data on the operation and results are presented in Tables III and IV. The sewage flows reflect in some degree a greater amount of storm water in periods III and IV than in periods I and II. The flow charts indicate two rains in period III and one rain in period IV. The effect of rain is reflected in the deviation of daily flows from the weekly average. In periods I and II the daily flow did not vary by more than 4 per cent of the weekly average, whereas in period III the daily flow varied from + 17.5 to − 11.6 per cent of the average, and

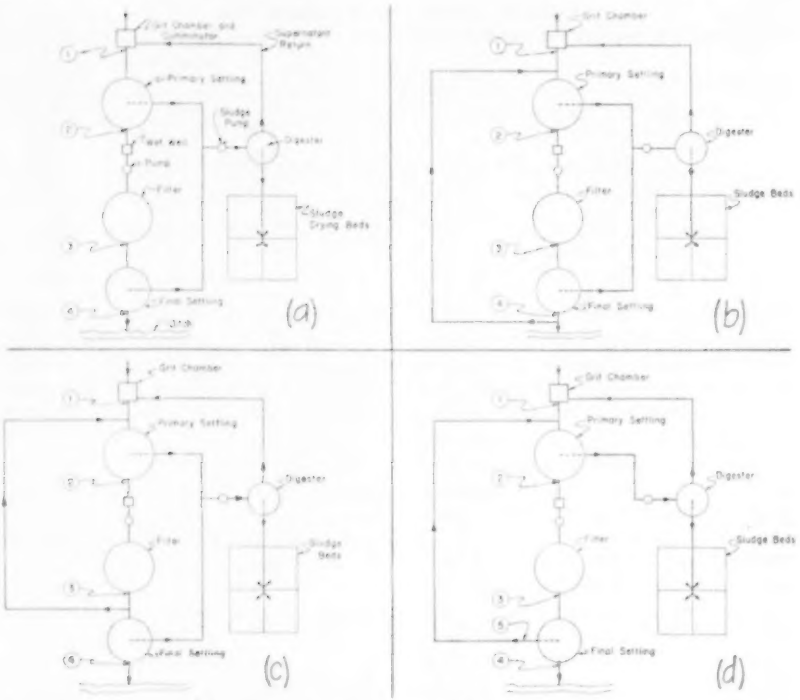

FIGURE 1.—Flow diagrams for studies on a shallow trickling filter, showing: (a) Period I, no recirculation; (b) Period II, recirculation of final effluent; (c) Period III, recirculation of filter effluent; (d) Period IV, recirculation of final tank underflow.

in period IV the daily flow varied from + 5.2 to − 10 per cent of the weekly average.

The detention periods and overflow rates indicate a considerable degree of overdesign of both primary and secondary settling tanks (detention periods of 4.3 to 16.4 hr. depending on the operating procedure) and reflect quite clearly the effect of recirculation on the hydraulic characteristics of the plant. Thus, the recirculated flow in three periods was always returned to the primary influent, thereby decreasing the detention period in the primary settling tank. The recirculated final effluent in period II also decreased the final settling tank detention and increased the effluent overflow rate. Recirculation of filter effluent did not affect the hydraulic conditions of the final settling tank over that of no recirculation in period I. Recirculation of final tank underflow in period IV, which was increased in volume over previous periods, reduced the detention time of both the primary and, particularly, the final settling tank without increasing the final settling tank overflow rate. Furthermore, in this period all of the secondary tank sludge was returned to the primary tank for resettling and thickening along with the raw sludge, and the depths of the final settling tank were purged or "freshened" more frequently by the recirculated flow.

The results show that the temperature of the sewage or sewage plus recirculated flow varied by 4°C. during

the entire study and the average temperature of the first period was 1° to 2° warmer than succeeding periods. It may be pertinent to call attention to the observed algal growth in the final tank during period III and the copious algal growth in the final tank in period IV, as reflected in the final effluent dissolved oxygen values. In period IV the dissolved oxygen of the effluent exceeded saturation values.

The total and volatile suspended solids and 5-day B.O.D. of the raw sewage indicates average strength domestic sewage. The primary effluent suspended solids decreased with each

TABLE III.—Average Operational Data

Study period		I	II	III	IV
Date (1946)		6/28 to 7/5	7/6 to 7/12	7/13 to 7/19	7/20 to 7/26
Recirculation: Kind		None	Final Eff.	Filter Eff.	Final Tank[1]
Per cent of sewage flow		0	65	70	95
Flow (m.g.d.)	Raw sewage	0.09	0.095	0.102	0.098
	Recirculated	—	0.062	0.071	0.093
	Primary influent	0.09	0.156	0.173	0.190
Detention (hr.)	Primary tank	16.4	9.4	8.5	7.7
	Final tank	9.1	5.2	8.0	4.3
Overflow rate (g.p.d./sq.ft.)	Primary tank	96	168	168	205
	Final tank	132	232	151	145
Sewage temperature (°C.)	Average	19.3	20.5	21.5	21.0
	Maximum	20.3	22.2	22.9	22.8
	Minimum	18.4	19.1	19.9	19.6
Suspended solids (p.p.m.)	Raw sewage	321	270	354	309
	Primary effluent	82	72	62	58
	Filter effluent	80	63	59	40
	Final effluent	45	45	32	27
	Final underflow	—	—	—	44
Volatile susp. sol. (p.p.m.)	Raw sewage	209	191	254	217
	Primary effluent	52	54	44	43
	Filter effluent	56	42	44	27
	Final effluent	33	34	25	20
B.O.D. (p.p.m.)	Raw sewage	268	217	248	210
	Primary effluent	142	109	93	63
	Filter effluent	76	64	43	30
	Final effluent	41	42	26	14
	Final underflow	—	—	—	26
Dissolved oxygen (p.p.m.)	Raw sewage	0.7	0.6	0.5	0.4
	Primary effluent	0.8	1.4	1.1	1.1
	Filter influent	3.3	3.6	3.2	4.3
	Filter effluent	4.2	5.4	5.2	5.8
	Final effluent, A.M.	1.5	0.9	5.2	10.3
	Final effluent, P.M.	1.0	1.5	6.8	11.4
Ammonia N_3 (p.p.m.)	Raw sewage	23	20	25	26
	Final effluent	16	16	17	15
Nitrite N_2 (p.p.m.)	Filter effluent	1.9	0.8	1.6	0.9
	Final effluent	0.8	0.5	0.7	1.2
Nitrate N_2 (p.p.m.)	Filter effluent	0.2	0.1	0.2	0.6
	Final effluent	0.2	0.1	0.3	0.7
Kjeldahl N_3 (p.p.m.)	Raw sewage	47	39	42	46
	Final effluent	28	27	26	25

[1] Final tank underflow.

TABLE IV.—Average Plant Loading and Performance

Study period Recirculation: Kind		I None	II Final Eff.	III Filter Eff.	IV F.T. Underflow
Per cent of sewage flow		0	65	70	95
B.O.D. (lb./16 hr.)	Raw sewage	156	123	138	130
	Recirculated	—	15	17	13
	Primary influent	156	137	155	143
	Primary effluent	83	102	89	71
	Filter effluent	44	59	41	33
	Final effluent	24	24	15	9
B.O.D. removal (percentage)	Primary treatment	47	26	43	50
	Secondary treatment	71	77	84	88
	Over-all	85	81	89	93
Suspended solids (lbs./16 hr.)	Raw sewage	187	157	202	190
	Recirculated	—	16	23	23
	Primary influent	187	173	225	213
	Primary effluent	48	68	59	65
	Filter effluent	47	60	56	45
	Final effluent	26	26	18	17
Suspended solids removal (percentage)	Primary treatment	74	61	74	70
	Secondary treatment	45	62	69	74
	Over-all	86	83	91	91
Filter loading (lb./cu.yd.)	B.O.D.	0.87	1.06	0.94	0.74
	Suspended solids	0.50	0.71	0.63	0.68
Removal by filter (%)	B.O.D.	47	43	54	53

successive period, but all of the apparent improvement can be accounted for by simple dilution resulting from the recirculating flows. Similarly, the improvement in the B.O.D of the primary effluent in periods II and III over period I can be accounted for by simple dilution resulting from the recirculated flows. However, in period IV (the return of final tank underflow), the primary settling tank showed an additional reduction of 30 p.p.m., or 20 per cent more removal of B.O.D. over period I than could be explained by the additional dilution. Presumably the return of trickling filter floc was effective in improving the quality of the primary tank effluent, or, more pertinently, the B.O.D. load applied to the filter.

The B.O.D. loading to the filter was unusually low in this study, as it averaged 0.87, 1.06, 0.94, and 0.74 lb. of 5-day B.O.D. applied per cubic yard of media per day for the first to fourth week, respectively. The B.O.D. removal by the filter alone was 47, 43, 54, and 53 per cent of the applied load during the first to fourth study periods, respectively.

The results show a substantial improvement in final effluent quality by the recirculation of filter effluent and final tank underflow, but not for final effluent recirculation. The final effluent B.O.D. results were 41, 42, 26, and 14 p.p.m. for normal operation (I), recirculated final effluent (II), recirculated filter effluent (III), and recirculated underflow (IV), respectively. The final effluent suspended solids results for the same periods were 45, 45, 32, and 27 p.p.m., respectively.

Over-all plant removal of 85, 81, 89, and 93 per cent of applied B.O.D. was achieved during the four test periods, respectively. For the same periods, over-all plant removal of suspended solids loadings of 86, 83, 91, and 91 per cent was achieved. The plant efficiencies may be considered excellent for this type of plant even without re-

circulation, but recirculation as shown for filter effluent and final tank underflow improved the over-all plant efficiency to a substantial degree. The return of underflow brought all of the plant sludges to the primary tank for thickening before discharge to the digester. Records are not available on how much less sludge volume went to the digester or, more pertinently, the volume and quality of supernatant liquor returned and its effect on plant efficiency.

The nitrogen values appear quite similar, except that there was slightly greater nitrification in period IV (recirculated underflow) where the trickling filter B.O.D. loading was considerably less, due to greater B.O.D. removal by the primary settling tank.

Summary

During the month of July, 1946, the Centralia, Mo., primary settling, trickling filter sewage treatment plant was studied by the U. S. Public Health Service. Following a week of study under normal operation with no recirculation, the flow through the over-designed plant was increased by recirculating successively for a week each, final tank effluent, trickling filter effluent, and final tank underflow. With nominal attention and without recirculated flows the sewage plant produced an over-all efficiency of 85 and 86 per cent removal of B.O.D. and suspended solids, respectively, or a final effluent quality of 41 p.p.m. B.O.D. and 45 p.p.m. suspended solids. Recirculation of secondary treatment plant flows to the plant influent improved the plant performance. Thus, following two weeks of recirculation and with the return of final tank underflow equal to 95 per cent of the sewage flow, the over-all plant efficiency was found to be 93 and 91 per cent removal of B.O.D. and suspended solids, respectively, or a final effluent quality of 14 p.p.m. B.O.D. and 27 p.p.m. suspended solids.

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Industrial Wastes

ANALYTICAL PROCEDURES FOR THE DETERMINATION OF PHENOLS IN WATER AND TRADE WASTES *

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This paper is intended to: (1) present a general description of several of the better known procedures for phenol determination, with a brief discussion of the advantages and disadvantages of each; and (2) describe rather carefully the procedure being used at the Ohio Department of Health Laboratories, giving special attention to the features found by past experience to be most likely to cause some difficulty.

The first method discussed is that presented by Shaw (1), who originally used a turbidimetric procedure based on the cloudiness developed by the reaction of bromine with phenol and, theoretically at least, all three cresols (ortho-, meta-, and para-).

Partial removal of some interfering substances is effected by steam distillation of an acidified portion of sample not to exceed 10 ml. This preferably is accomplished with a special steam chest, although improvised equipment may be used. Inasmuch as 25 ml. of the distillate is collected, the sample is diluted at least 2½ times in this step. The actual comparison is made with standards, and the range necessary is 30 to 35 p.p.m. of phenols. Hence, it is necessary to take successive dilutions, using portions of the 25 ml. of distillate, until the range of the standards is reached. The phenol content is calculated from the factors involved in (a) the ratio of original sample to the final volume (25 ml.) of distillate, and (b) the extent of dilution of the distillate to reach the 30- to 35-p.p.m. range.

This method possesses the distinct advantage of time; the entire determination can be done in less than 1 hr. It also must be remembered that it is for high phenol content only, the lower limit being 75 p.p.m. (equivalent to 30 p.p.m. in the distillate, which is diluted at least 2½ times). It is said, by some who have used this method extensively, that it is not necessary to prepare any standards; and that an experienced observer can read the phenol content from the mental picture he retains of the turbidity caused by 30, 31, 32, 33, 34, and 35 p.p.m. of phenols. The authors are not able to confirm or deny this statement, but would not attempt to make any report on a phenol sample without actual comparison against standards. It also must be noted that, with a dilution of only 2½ times, slow distillation must be used if complete phenol recovery is to be obtained on samples high in phenol.

As previously stated, the original Shaw method is limited to phenol con-

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tents of 75 p.p.m. or more. However, in a modification published by Shaw two years later (2) the phenols are concentrated by an extraction process, after which the turbidity development with bromine is followed. In this manner it is stated that samples as low as 1 p.p.m. phenols can be analyzed. Basically, the concentration is accomplished by extracting up to 900 ml. of acidified sample with several successive portions of diethyl ether, using a 1,000-ml. separatory funnel. The ether extracts are combined and the phenols removed by three successive washes with 10 per cent sodium hydroxide and 1 rinse with distilled water. The alkaline and aqueous portions are combined and boiled gently to remove the ether, cooled and brought to volume, and aliquots selected (to fit in the necessary 30- to 35-p.p.m. range), then acidified, diluted, and treated with bromine. This modification thus extends the lower limit of the original method, but at the expense of shortness of time, as the extraction involves several extra manipulations.

Another method briefly studied by the authors is a volumetric determination outlined by R. D. Scott (3). This method consists of the treatment of phenols with a measured amount of bromide-bromate solution, then potassium iodide and acid, followed by titration of the iodine released by the excess bromine. The method involves preliminary distillation of concentrated samples, which in some cases is quite difficult. It also requires removal of sulfites and similar compounds which would interfere with the final titration. This procedure is for very high phenol concentrations, and probably is of very limited application in coke plants.

The Gibbs-Sanchis colorimetric method (4) as modified by R. D. Scott (3), is considered the best suited for general use. This method is a colorimetric procedure using the Gibbs reagent (2-6 dibromoquinone chloroimide) to develop a green-blue color with phenols, a purple color with ortho-cresol, and a blue color with meta-cresol. (No color is developed with para-cresol.) The sample is freed from some impurities by distilling a slightly acidified portion, and treating various dilutions of the filtrate—after buffering to about pH 9.2 to 9.4—with the Gibbs reagent. This method has several disadvantages in that (a) it does not react with para-cresols, (b) it requires the standards to be blended according to the approximate phenol-cresol ratio present, (c) it requires distillation and overnight color development, and (d) it requires extensive dilution for high phenols. However, it is sensitive in the fairly low range (from 25 up to 1,000 p.p.b.), which is of primary concern in regard to taste and odor problems in water supplies. By diluting the sample before distillation, the useful range can be extended to the higher ranges with an accuracy as good or better than methods that were especially devised for higher ranges only. In the light of present data it has not been felt desirable to change from this method to any other procedure, even for the higher phenols. However, this does not mean that it is suggested that industrial laboratories, dealing extensively in the higher ranges, dispense with either of the Shaw methods. It is felt, nevertheless, that the Gibbs-Sanchis Scott method (3) is the most versatile for general use, especially where the best accuracy is desired.

The Gibbs-Sanchis method (4) has been the subject of much study, and numerous modifications have been suggested. One of the more promising, as proposed by N. R. Brown and L. B. Miller (5), has been tried but found to be unsuited for the purposes of the Ohio laboratory. In this method the color developed is extracted with a small volume of an alcohol such as N-butyl alcohol, and thus concentrated, with the idea of (a) extending the lower range of usefulness

and (b) reading by an instrument such as a colorimeter or spectrophotometer, thereby eliminating visual comparisons and preparation of standards for each set of determinations. Observations indicated that this procedure was more or less restricted to relatively pure water solution of phenol—enough interfering substances were distilled over from polluted samples to cause considerable error in the alcoholic extraction. Even with pure solutions there seemed to be little or no improvement in the accuracy, and there was a definite loss of time.

Method in Use

So much for the discussion of phenol determination methods. It is assumed that everyone concerned with this phase of work is more or less familiar with the Scott modification (6). On this basis, the essential features as used in the Ohio laboratory will be described step by step, with references to the precautions necessary in each stage.

1. Very little need be said about sampling, except that the accuracy of any analysis can be no better than the accuracy of sampling. Hence, every effort should be made to secure a truly representative sample.

2. Preservation of the sample is very important. Unless analysis is to be made within a few hours, the sample should be preserved by adding approximately 1 gram of copper sulfate crystals for each liter of sample. Samples so treated may be stored for two or three days at average room temperature with very little loss of phenol. If kept refrigerated, they may be kept for a week or two with little change. Without the copper sulfate, the loss of phenols may be quite rapid, even if kept under refrigeration.

3. High phenol samples may be analyzed by diluting either before or after distillation. Because of the possibility of not condensing all the phenols from higher ranges, it is considered better to dilute the sample just before distillation, using the following table as a guide:

Probable Phenol Content (p.p.m.)	Dilution
0.01 to 1	None
1 to 10	100 to 1,000
10 to 100	10 to 1,000
100 to 1,000	1 to 1,000 (in 2 steps)
1,000 to 10,000	1 to 10,000 (in 2 steps)

In preparation of dilutions it is recommended that only the settled supernatant (rather than mixed sample) be used. Furthermore, only good quality distilled water, or double-distilled water, should be used for dilution.

4. The methyl orange alkalinity of the sample should be determined on a separate portion, and then the necessary amount of acid required for 220 ml. be added to that amount of sample. It is advisable to keep the total volume of acid added in this step to 5 ml. or less.

5. As regards distillation, cleanliness is an item that cannot be emphasized too much. The flasks should be carefully and thoroughly cleaned, and then the flask and condenser steamed by placing distilled water in the flask and boiling for several minutes with no cooling water in the condenser. The still should be all pyrex glass with glass stoppers and joints. Also, if a very loose plug of pyrex glass wool is inserted in the arm of the distillation flask, carry-over of copper sulfate can be minimized. In the case of very low phenols, this carry-over may involve some error and result in a high reading.

A 220-ml. portion of the settled sample or diluted sample, after being neutralized, is placed in the empty, clean flask and the Bunsen burner adjusted so as to provide a rate of distillation of 6 to 7 ml. per min. Exactly 200 ml. of distillate is collected in a glass stoppered 200-ml. volumetric flask, which has been thoroughly cleaned and dried. If the distillate is

not prepared for color development at once, it should be refrigerated until that time, which should be the same day.

There may be some question about the ratio of volume of sample and distillate. However, the phenols present in the 220-ml. portion placed in the distilling flask do not all come over in the 200 ml. of distillate. Careful checks in the laboratory show that there is almost exactly the same concentration of phenols in the distillate as in the original portion. Hence, if the 220 ml. of sample contained 0.1 p.p.m. phenols, the 200 ml. of distillate will contain 0.1 p.p.m. and the residue in the flask will have 0.1 p.p.m. (In other words, 10/11 of the phenols come over with the 10/11 of the volume distilled over; 1/11 stays with the 1/11 of the volume remaining in the flask. The ratio of 220 to 200 does not enter in any way into the calculations for phenol content.)

6. In the preparation of aliquots, portions of the 200-ml. distillate are placed in perfectly clean 100-ml. Nessler tubes. Either the tall or short form tubes may be used, but the tall form is preferred in the Ohio laboratory. The aliquots used usually start with 100 ml. and continue on down to 50, 25, and, if necessary, further on to 10, 5, 2, and even 1 ml. The tubes are then filled exactly to the 100-ml. mark with either double-distilled water, or single-distilled water of excellent quality. Next, 5 ml. of buffer solution is added to each tube. This buffer is prepared by dissolving 3.1 gm. of boric acid and 3.5 gm. of potassium chloride in about 800 ml. of distilled water. Next, the equivalent of 1.28 gm. of NaOH is added, usually as 32 ml. of a 1N solution, and the volume is then brought to 1 liter. This buffer, when diluted by adding 5 ml. to 100 ml. of distilled water, should have a pH value of 9.4.

7. Stock solutions of phenol and ortho-cresol may be prepared and kept on hand for several months if refrigerated. Otherwise it is necessary to prepare them each time. The stock phenol is prepared by weighing 1 gm. of C. P. or reagent grade phenol, and bringing to 1 liter with distilled water. The ortho-cresol is prepared by placing 1 gm. of o-cresol (Eastman Kodak No. p-81) in a 1,000-ml. volumetric flask, adding 12 ml. of 1N NaOH, and bringing to 1 liter after the cresol is dissolved in the caustic.

In preparing the "working" standard solution, the total volume of stock phenol plus stock cresol is 10 ml. per liter (using good distilled water for dilution). The relative amounts of phenol, which gives the blue color, and ortho-cresol, which gives a purple color, usually are determined by past experience. Until the proper ratio is determined, it may be advisable to prepare 2 or 3 sets of standards, using, say:

(a) 5 ml. of phenol and 5 ml. of o-cresol;
(b) 7½ ml. of phenol and 2.5 ml. of o-cresol; and
(c) 10 ml. of phenol only.

In any case the analyst must exercise his own judgment as to the selection of the best ratio. Because the meta-cresol gives a color comparable to phenols and also is not usually present in very large amount, it is not needed in the preparation of color standards. In the Ohio laboratory, the most generally used proportion is 5 ml. of stock phenol and 5 ml. ortho-cresol diluted to 1 liter with good quality distilled water. This solution is then used to prepare the color standards in the Nessler tubes. Standards may be prepared using 0, 0.05, 0.10, 0.20, 0.30, 0.50, 0.60, 0.80, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.5, and 4.0 ml., representing respectively 0, 5, 10, 20, 30, 50, 60, 80, 100, 120, 140, 160, 180, 200, 220, 240, 260, 280, 300, 350, and 400 p.p.b. However, although it is generally found unnecessary to take this many stand-

ards in such close increments, it should be recognized that over 3.0 ml. is too dark for any but approximate readings, and under 1.0 ml. is too pale for extreme accuracy; hence, the desirability of selecting aliquots of sample that fall in the range covered by 1.0 to 3.0 ml. of standard. After the proper amount of the standard is placed in the Nessler tubes, good distilled water (or double-distilled) is used to bring all tubes to the 100-ml. mark and then 5 ml. of the buffer solution is added.

8. The color developing agent, called Gibbs reagent, is technically named 2-6 dibromoquinone chloroimide. It is used as a freshly prepared alcoholic solution containing 0.04 gm. of reagent in 10 ml. of 190-proof alcohol. This reagent is not stable in solution form and is preferably prepared fresh each day used. It is emphasized that the crystalline or powder form also deteriorates with age and a fresh supply should be procured every 6 to 12 months. As the material ages the color reaction is not only slower, but also less distinct. It is strongly advised that the reagent be replaced at frequent intervals. In actual use, the amount of alcohol solution to be added to each Nessler tube, both the standards and sample aliquots, is 2 drops, no more or no less. Although addition of 3 drops seems to make little difference in higher ranges of color, this amount reduces the accuracy of comparison in the ranges less than 1.0 ml. of standard. Another important step is thorough mixing of sample (or standard) after all reagents have been added to the Nessler tube. It has not been found necessary to mix between successive additions, but complete mixing is definitely called for after the final addition. It has been found that the tall form Nessler tubes can be well mixed by placing the top against the thumb or forearm, and inverting the tube slowly three times. After this step the tubes may be set aside to allow color development overnight. In case a limited number of standards, or aliquots of sample, have been prepared, it is well to check the color after ½ to 1 hr. to be sure that both standards and sample are in the desired range. If not, additional tubes should be set up.

9. After overnight color development, the tubes should be read by viewing lengthwise, comparing with the standards. As stated earlier, it was found that the sample aliquots comparing with the 1.0- to 3.0-ml. range of standards are most accurate. It is good practice to prepare a sufficient number of sample aliquots to have at least two, and preferably three, within the range that can be read. It is sometimes found that one tube may be completely out of line with the others, in which case the reading for this tube should be disregarded.

10. Where the original sample is distilled without previous dilution, the phenol content is calculated as:

$$\text{p.p.b.} = \frac{10{,}000 \times \text{ml. of standard}}{\text{ml. of distillate used in Nessler tube}}$$

$$\text{p.p.m.} = \frac{10 \times \text{ml. of standard}}{\text{ml. of distillate used in Nessler tube}}$$

Where the sample is diluted prior to distillation, the above results must be multiplied by the appropriate factor.

Summary

In summarizing, it is suggested that the Scott modification of the Gibbs-Sanchis method be used for phenol analysis, especially in the lower concentrations, bearing in mind these general precautions:

(a) Extreme care should be taken in cleansing of glassware used in this test.

(b) Diluting water used should be distilled water of very high purity. If in doubt, double-distilled water should be used.

(c) All reagents should be purchased

with special attention to their purity, and, in the case of the indicator, a reasonably fresh material should be used.

(d) Stock solutions of phenol and ortho-cresol should be kept in the refrigerator or prepared fresh each time. The indicator solution should be prepared each time.

(e) Samples should be taken carefully, preserved with 1 gm. per liter of copper sulfate, and kept under refrigeration if possible.

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RADIOACTIVE WASTES HANDLING

"Handling Radioactive Wastes in the Atomic Energy Program," a U. S. Atomic Energy Commission report published in October, 1949, describes radioactive waste materials, their sources in the atomic energy program, and the methods used in processing and storing or disposing of them at atomic energy installations and at laboratories and hospitals using radioisotopes.

Of particular interest to sewage and industrial wastes treatment personnel and planners is the chapter dealing with the handling of wastes resulting from the radioisotopes distribution program. All shipments of radioactive materials made thus far have been for experimental purposes only, the vast majority being of radioisotopes having short half-lives or low-energy dilutions. Disposal of laboratory and clinic radioactive wastes is usually by dilution with non-radioactive isotopes of the same element, followed by dilution with large amounts of organic matter and water when discharged to the ordinary sewerage system. Rigid controls have been established on the isotope users to insure adequate provisions against harmful discharges.

Copies of the 30-page pamphlet are available from the U. S. Government Printing Office, Washington, D. C., at a price of 15¢.

PHENOL RECOVERY FROM BY-PRODUCT COKE WASTES *

ARMCO STEEL CORP., NEW MIAMI, OHIO

By Frank Wilks

Superintendent, By-Product Coke Plant

The dephenolizing process used at the Hamilton plant of the Armco Steel Corporation is based on the fact that phenol has an appreciable vapor pressure, particularly at temperatures of 100° C. or higher. The principle of this process is the continuous recirculation of steam vapor, first through hot ammonia liquor containing phenol to remove phenol from the liquor, and then through hot caustic soda solution to absorb the phenol present in the steam.

The dephenolizing plant at Hamilton was placed in operation in 1928. It consists of a tower 7 ft. in diameter and 94 ft. high, divided into four sections (Figure 1); a motor-driven blower for circulating vapor; pumps for ammonia liquor and caustic; and the necessary auxiliaries such as storage tanks, piping, temperature controllers, thermometers, pressure gauges, and flow meters. The whole system is insulated so that very little heat is lost.

In the dephenolizing process, ammonia liquor at a temperature above 100° C. is taken from the bottom of the free leg of the ammonia still and pumped to the top of the dephenolizer by the hot ammonia liquor pump. Here the liquor is distributed through a header and six ¼-in. splash plate sprays over wooden hurdles, which make up the packing in the upper or ammonia liquor section of the tower. In this section the phenol is removed from the liquor by the counterflow of saturated vapor, which is circulated up through the tower by the blower. The vapors containing the phenol are removed from the top of the ammonia liquor section and delivered through a downcomer and blower to the bottom of the tower. From here the vapors pass upward through the three lower packed sections of the tower, where the phenol is scrubbed out with a solution of caustic soda. The vapor then passes upward into the ammonia liquor section clean and capable of absorbing more phenol.

The dephenolized liquor, after being scrubbed with vapor while passing down through the packing, collects in the well at the bottom of the ammonia liquor section and flows back to the lime mixing chamber of the ammonia still. Fresh caustic solution is added in shots to the top of the shot section of the tower, the third section from the bottom. As the caustic flows down through the tower it is converted into sodium phenolate by absorption of phenol from the vapor. This partially converted solution can be recirculated over either one or both of the two lower sections of the tower if more complete conversion of the caustic to phenolate is desired. The phenolate solution is then discharged to a storage tank, from which it can be blown to the springing tank for final disposition. Because the crude phenol is removed from the liquor and transferred to the caustic as a vapor, an excellent uncontaminated product is recovered. The crude phenol separated from the

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phenolate in the springing tank contains 20 to 40 per cent water and a small amount of sodium carbonate or bicarbonate, which can be readily removed by treatment with strong acids. The specific gravity of this material is usually 1.06 to 1.08. The tar acid content of this material (60 to 80 per cent of the total) is made up of approximately 80 per cent phenol (C_6H_5OH) and 20 per cent homologous tar acids higher in the series, principally cresol.

FIGURE 1.—Tower for recovery of phenol from hot ammonia liquor by caustic.

Operation

The amount of phenol in the liquor withdrawn from the storage tank varies considerably with the coking time. The longer the coking time, the more phenol in the liquor. At Hamilton over the past 20 years the coking time has ranged from 13 hr. to 22 hr., and the phenol from 500 to 4,500 p.p.m.

The ammonia should go through the still and dephenolizer as free from tar, braize, and other solids as possible. For this reason a constant discharge is kept running from the tar drain of the storage tank. In addition, the drain valve is opened wide for a few minutes every 2 to 4 hr. so that any accumulation of tar or muck will be drawn off.

The ammonia liquor is pumped from the storage tank to the top of the free leg of the ammonia still, where it is subjected to steam distillation. As this liquor passes down through the free leg of the still its volume is increased about 25 to 30 per cent by condensation of some of the steam. Also, a certain amount of phenol is removed here, depending on the amount of steam used in the still and the temperature of the vapor leaving the still. The liquor then goes from the bottom of the free leg of the still, at a temperature usually between 104° and 106° C., to the hot ammonia liquor pump containing less phenol by volume due to this dilution. The liquor must be at least 100° C. at this point to make certain that the carbon dioxide has been driven off, as CO_2 absorbed by the caustic in the dephenolizer carbonates the caustic and thereby decreases the phenol absorbing capacity of the caustic. Excessive CO_2 would make it necessary to use excessive quantities of caustic to properly dephenolize the vapor.

The liquor is delivered by the pump

to the spray header on the top section of the tower.. The liquor undergoes a temperature drop of about 1.5° between the pump and the spray header and enters the sprays at 102° to 105° C. The temperature drop of the liquor in the ammonia liquor section of the tower depends on atmospheric temperature and the pressure under which the dephenolizer is being operated. The temperature of the liquor as it returns to the still is usually 100° plus or minus 2°. The sprays are rodded out once a week. Care is also used in setting the valves on the leads from the header to the sprays after rodding so that good distribution of the liquor over the packing and good removal of phenol is obtained.

Caustic is received in the form of 50 per cent solution containing about 6 lb. of NaOH per gallon, and is stored in a 12,000-gal. tank. This strong caustic can be diluted in the storage tank by filling the tank with water after the 50 per cent solution has been unloaded into it, thereby minimizing the tendency for the caustic to crystallize out of solution in cold weather. The tank is equipped with a steam coil, which can be used when necessary. As the solution is withdrawn, further dilutions of the caustic in storage can be made if desired.

From the storage tank the strong caustic is drawn into a 400-gal. mixing tank, where it is diluted to the desired strength before being delivered to the tower by the shot pump. This tank is 4 ft. deep and holds approximately 8 gal. to the inch of depth. The strength to which this solution is made up can be most conveniently determined by taking its specific gravity. The best strength to use depends on the shot frequency desired and the desired percentage conversion of caustic to phenolate. It seems generally satisfactory to use a solution containing 8 to 10 per cent NaOH, which has a specific gravity of 1.09 to 1.11. At present the tower is being given an 8-gal. shot of caustic (s.g. 1.09) every 45 min. This is 32 shots (or 256 gal.) per day, which is equivalent to about 190 lb. of NaOH daily. This is satisfactory for a still feed of about 2,000 gal. per hr. Weaker solution can be fed if it is desired to make larger or more frequent shots or to keep the tower at higher pressure.

Only two adjustments are necessary to regulate the shot apparatus. The meter or regulator after the shot pump is set for the volume desired per shot—8 gal., for example—and the right hand dial of the timer on the instrument board is set at the desired interval between shots—say 30 min. The pressure relief valve in the line immediately after the pump should be set for 35 lb. pressure and should not be tampered with. A good check on the regularity of operation of the apparatus can be obtained by measuring the caustic in the mixing tank twice a shift.

The caustic solution drips down through the packing of the shot section and upper recirculating section and collects in the well at the bottom of this latter section, which eventually overflows and allows the solution to continue to the lower well. Thus, when there is no recirculation the whole caustic section of the tower acts as one shot section.

Removal seems equally as good with still feeds of 2,000 gal. per hr. or less, when the tower is used this way as when the caustic is recirculated. However, for higher liquor rates or when high saturation (conversion to phenolate) is desired, recirculation over the lower section can be used to advantage. With recirculation here the bulk of the phenol is removed from the vapor in this section. However, without recirculation the shot section does most of the work. It will probably not be necessary to recirculate over the upper section at any time. The wells in both recirculating sections are equipped with steam coils regulated by temperature controllers. These controllers are

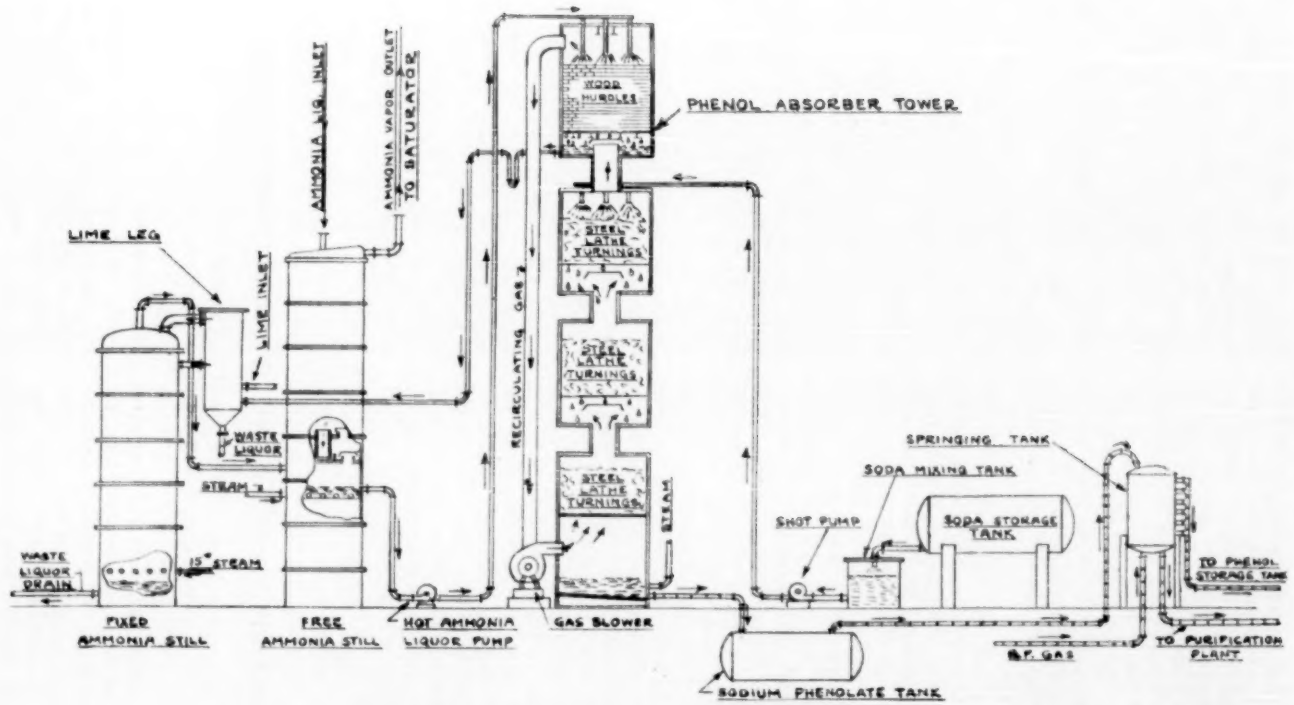

FIGURE 2.—Flow diagram of Armco Steel Corp. phenol recovery apparatus at Hamilton, Ohio.

set so that the caustic solution is kept at such a temperature that the phenolate discharged to storage has the desired specific gravity, usually 1.11 to 1.14. Temperatures of 104° to 106° C. in the upper well and at the lower pump (when it is in operation) are usually satisfactory. When there is no recirculation over the lower section the controller setting can be regulated according to specific gravity determinations.

It makes no apparent difference what strength caustic is used in the dephenolizer. Solutions containing from 4 to 20 per cent NaOH have been used and found to scrub the vapor about equally well. However, solutions containing 10 to 12 per cent NaOH equivalent are best adapted to springing. The higher the conversion to phenolate the lower the percentage of phenol loss when the solution is treated in the springing tank. The plant has been run with the caustic more than 70 per cent converted, but 30 to 50 per cent is more general practice. The degree of conversion is determined conveniently by the "saturation test." Pressure, as such, from atmospheric to 5 lb. seems to have very little effect on phenol removal. However, it is desirable that the ammonia liquor be kept near its boiling point while in the dephenolizer, and operating under 2- or 3-lb. pressure is a convenient way to accomplish this in cold weather (4.5 to 5 lb. is the maximum operating pressure with the present system of seals and vents, and there is no reason for exceeding this limit). The desired pressure can be maintained by adding fresh caustic as more dilute solution—say 4 to 6 per cent—and concentrating it to 10 or 12 per cent in the tower, or by making direct additions of live steam to the recirculating vapor, keeping the fresh caustic at the usual strength.

The Hamilton dephenolizer was placed in operation in 1928 as previously mentioned. Numerous improvements have been made since that time. For example, all modern installations are equipped with continuous liquor filters to assure a feed to the ammonia still and to the dephenolizer of ammonia liquor substantially free of tar, coke breeze, and other insoluble impurities. The caustic shot and recirculating sections of the dephenolizer tower have been replaced with one small section containing bubble cap trays. In the latter case, the caustic is fed continuously through a meter to the top tray of the section. The feed rate is regulated to obtain maximum conversion of the caustic to phenolate before being discharged from the base to storage. Although the Hamilton unit performs entirely satisfactorily, it is apparent that the newer installations with their improvements would accomplish the desired high removal of phenol from the waste liquor with even fewer operating problems.

ALLIED CHEMICAL AND DYE CORP., IRONTON, OHIO

By Walter E. Carbone

Engineer, Wilputte Coke Oven Division

The initial installation for removal of phenol from the waste effluent disposed of by the Semet-Solvay Division by-product coke plant at Ironton, Ohio, and discharged into the Ohio River was placed in operation on May 29, 1928. Prior to selection of the process and design of the facilities, a comprehensive study was made of the available methods developed for the prevention of objectionable taste and odor in public water supplies originating and

caused by phenol-bearing waste waters. Numerous processes yielding removal efficiencies exceeding 90 per cent and satisfactory to the public health authorities were examined. However, due to a variety of disadvantages, the majority were found unsuitable for the specific application under consideration. The factors influencing the final choice were ground area and equipment requirement, continuity and flexibility of operation, and general economics in conjunction with investment, operation, and maintenance; it was found that the process which satisfied these conditions most adequately was the benzol washing method.

The underlying principles in the benzol washing method are cyclic liquid and chemical extraction, whereby phenol is absorbed from solution by a vehicle, which subsequently is treated chemically for the liberation of phenol, and thence recycled for further absorption. As applied to by-product coke oven plants the effluent requiring treatment before final disposal is weak ammonia liquor, which in addition to containing phenol, has variable quantities of ammonia, hydrogen sulfide, carbon dioxide, and other acidic constituents. Phenol is the first compound to be removed in the by-product operation train. In a succeeding step ammonia, hydrogen sulfide, and carbon dioxide are removed by distillation. The remaining liquor, containing small quantities of calcium salts, is discharged as waste effluent. Coke oven light oil or its benzol derivative is used as the vehicle for absorption of phenol, and caustic soda solution is universally used in the chemical extraction step. The reaction taking place in the final stage of phenol extraction results in the formation of readily disposable and marketable sodium phenolate; sometimes further treatment of this end product is undertaken to reduce transportation costs in delivery to the refiner.

Design Considerations

The basic mechanics to be considered in the design of equipment for this process comprise countercurrent fluid flow, suitable means to afford intimate contact between the two fluids (attainable by liquid particle dispersion, surface media, or a combination of both), and sufficient contact time for absorption and reaction. These factors are normally applied in one or more absorption stages, consisting of closed vessels, wherein the light oil flows vertically upward and countercurrently to the downward flow of the phenol-bearing weak liquor. Phenol is absorbed during this flow action, and the phenolized light oil thence passes through two series-connected caustic washers, consisting of closed vessels containing static beds of caustic soda solution, wherein it is denuded of phenol. In the past, several installations have been made incorporating these essential features with varying degrees of success, and at the time of the Ironton design it was determined that the factor having the greatest influence in obtaining maximum removal efficiency was a high degree of liquid to liquid contact. Therefore, considerable study was devoted to developing the most efficient means to obtain this prerequisite.

The original phenol removal plant installed at Ironton utilized a countercurrent spray system whereby the weak liquor and light oil were finely dispersed through orifices drilled in distributing spray pipes. This method gave excellent performance and yielded removal efficiencies exceeding 90 to 95 per cent. In addition, an auxiliary piece of equipment—termed a sulfur washer—was introduced in the cycle to scrub the phenolized light oil with water prior to the caustic extraction, the wash water being returned to the phenolized weak liquor. This was a very valuable addition, as it removed more than 50 per cent of the hydrogen sulfide and carbon dioxide taken up

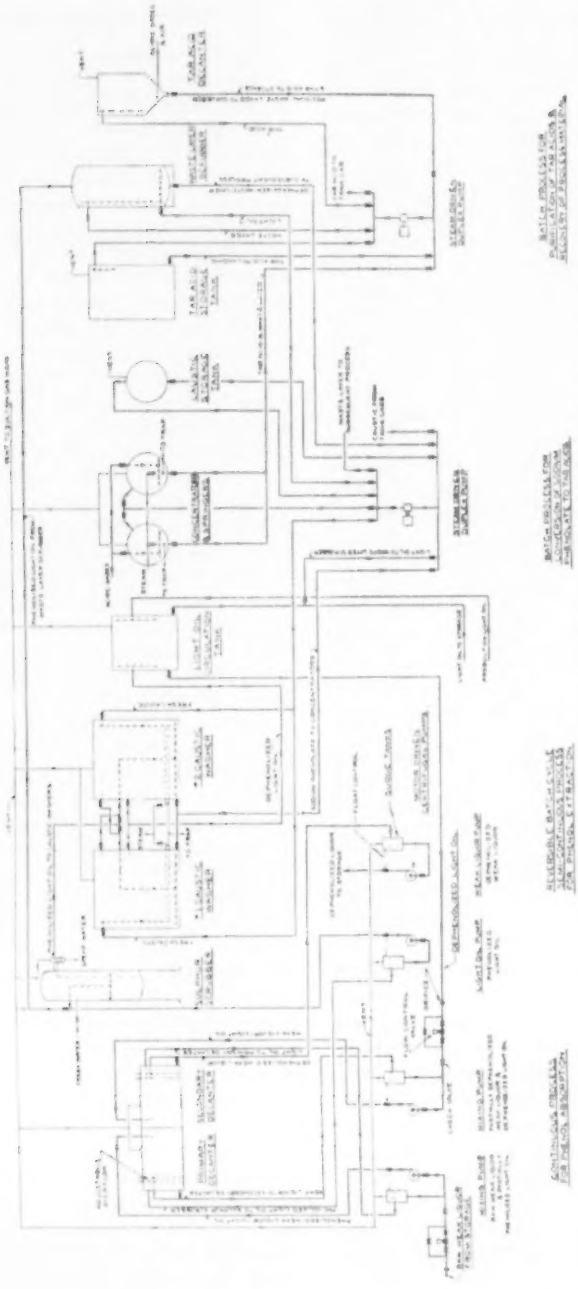

FIGURE 3.—Flow diagram of Semet-Solvay Division phenol recovery installation at Ironton, Ohio.

by the light oil in passing through the weak liquor. In this manner a reduction of caustic soda consumption was effected, thereby substantially improving the economy of the process.

At a later date, in an effort to reduce capital investment, a phenol removal plant was designed and installed by the Semet-Solvay Engineering Division for an Indiana by-product coke plant, effecting intimate contact in the absorption stage by mechanical mixing of the weak liquor and light oil in centrifugal pumps and then permitting the two fluids to separate by gravity differential in two vertical decanters. It was found that, in addition to reducing installation costs, this method provided more uniform fluid contact and resulted in improved removal efficiencies. In 1941 the Ironton coke plant expanded its coal carbonizing capacity and in conjunction therewith installed new phenol removal facilities, designed by the Wilputte Coke Oven Division in accordance with the experience obtained from the Indiana installation and utilizing the mechanical mixing and gravity decantation concept. This installation is successfully dephenolizing raw weak liquor from an initial concentration varying between 0.8 and 2.0 grains per liter to an outlet concentration consistently between 0.1 and .04 grains per liter (usually averaging .06 grains per liter), representing a phenol removal efficiency of 95 to 98 per cent.

The phenol removal plant at Ironton consists of the following equipment:

1. Two weak liquor-light oil decanters, connected for series operation, and termed as primary and secondary units.
2. One sulfur scrubber.
3. Two light oil-caustic washers, connected for series operation.
4. One light oil circulation tank.
5. Five motor-driven centrifugal pumps.
6. Two combination sodium phenolate concentrators and springers.
7. One caustic storage tank.
8. One waste layer scrubber.
9. One tar acid decanter.
10. One tar acid storage tank.
11. Two, general service, horizontal, steam-driven duplex pumps.

Two Operation Phases

The operation at Ironton may be considered as progressing in two separate phases: first, the absorption and extraction of phenol as dilute sodium phenolate; and second, the conversion of sodium phenolate to concentrated phenol, or tar acid, and preliminary purification before shipment.

Extraction Phase

The process cycle comprising the first phase is as follows:

As discussed heretofore, the flow of weak liquor and light oil through the phenol absorption equipment is strictly countercurrent. Raw weak liquor, which has been previously permitted to settle for separation of contaminating tarry materials, is combined with light oil flowing from the secondary weak liquor-light oil decanter, mixed in the first centrifugal pump, and discharged into the primary decanter, where the mixture separates into an upper layer of oil and a bottom layer of liquor. This operation is immediately repeated in the secondary decanter; oil flowing from the circulation tank is combined with the liquor overflow from the primary decanter, mixed in the second centrifugal pump and permitted to decant in the secondary unit. The dephenolized liquor is withdrawn from the secondary decanter and pumped to storage. The phenolized oil flowing from the primary decanter is pumped to the sulfur scrubber, where it is sprayed through a fresh water bath for the removal of approximately 50 to 60 per cent hydrogen sulfide and a proportionate amount of carbon dioxide, cyanide, and chloride constituents dissolved in the oil and contained in any entrained weak liquor. The incoming weak liquor and

light oil flows are governed by controllers and maintained in the ratio of approximately 1¼ oil to 1 of liquor. In both decanters the light oil overflows directly from the units through a weir box arrangement, and the weak liquor is withdrawn through adjustable overflows set to maintain a definite height of oil and liquor interface. In all cases, the fluid flows to the mixing pumps are regulated by means of surge tanks, equipped with float controls, to maintain uniformity of flow.

The phenolized light oil leaving the sulfur scrubber flows by gravity through the two series-connected caustic washers, where, by reaction with the caustic soda, the phenol is extracted in the form of dilute sodium phenolate. The light oil enters the bottom of the first washer and is sprayed through a static layer of dilute caustic soda solution by means of distributing pipes having drilled orifices. The oil passes slowly upward, overflows from the upper portion of the unit, enters the second washer for treatment similar to that in the first unit, and leaves the second stage practically free from phenol. The oil then flows by gravity to the light oil circulation tank, which serves the two-fold purpose of a reservoir for recycling the light oil to the secondary phenol absorption stage and a settling tank for any entrained caustic. In order to maintain a clean stream of light oil, the coke plant production of light oil is continuously introduced into this tank, and an equivalent amount withdrawn from the system for return to storage.

The operation of the light oil-caustic washers is a reversible batch cycle; the units are periodically interchanged in position as often as the caustic soda is depleted in the first stage, which occurs approximately every 12 to 14 days. At this time, the oil flow through the first caustic washer is temporarily suspended and the sodium phenolate solution is drained to a concentrator, while the second caustic washer is continued in operation. Following the draining, the washer is recharged with a fresh caustic solution and returned to service. However, it is placed second in position, the other unit with the partially spent caustic assuming the first position in the series arrangement. When a unit is recharged, it is filled with approximately 10,000 gal. of aqueous caustic soda solution (250 grains per liter), equivalent to a 5–ft. layer of fluid. At the end of the reaction period this charge has expanded to twice its original volume, producing 20,000 gal. of dilute sodium phenolate solution.

Recovery Phase

The process cycle comprising the second phase, or recovery of sodium phenolate as tar acid, is as follows:

Sodium phenolate as formed and drained from the first caustic washer has a concentration in the range of 18 to 25 per cent. This material is charged to a concentrator for processing and neutralization with acidic gases to form 80 per cent tar acids. The charge is first heated with indirect steam to recover any entrained light oil, and is then treated with a current of direct high pressure steam in order to remove final traces of oil and naphthalenes that may have been occluded. The sodium phenolate is cooled to a temperature of 40° to 45° C. and neutralized by a stream of acidic gases blown through the batch. The acidic gases are available from distillation of the dephenolized weak liquor, and consist principally of hydrogen sulfide and carbon dioxide. During this process the phenol is liberated, or sprung, from its metallic salt state, the sodium combining with the gaseous acids to form sodium carbonate, sodium bicarbonate, and sodium sulfide, which remain in solution as a residual or waste liquor layer below the sprung tar acid. After a suitable interval of settling, the tar acid is pumped to a decanter and the waste layer to a scrubber.

The tar acid is permitted to settle further in the decanter to assure removal of any residual waste layer, and then is purified by a final treatment with acid gases, followed by aeration to dispel retained hydrogen sulfide. Subsequent to a final settling period the tar acid is pumped to storage ready for shipment.

The waste layer pumped to the waste layer scrubber is treated with light oil for absorption of phenol not completely liberated in the neutralization step. The amount retained is usually 20 to 25 grains per liter, the oil extraction reducing this quantity to 1 grain per liter. The phenolized light oil accumulated in this secondary operation is pumped to the caustic washers for recovery of the phenol. The dephenolized waste layer is then utilized as a primary process material in a separate operation in the by-product sequence.

The recovery phase of tar acids described is a reasonably efficient process, 92 to 95 per cent of the phenol in the sodium phenolate being recovered by the springing, and 90 per cent of the remainder being recovered by washing the waste layer with light oil.

Throughout the various stages of the process as operated at Ironton, loss of light oil used in the cycle is practically non-existent. Each piece of equipment containing light oil is vented back to the suction gas main. Hence, any escaping vapors are diverted to the main gas stream and recovered along with the regular production oil. Light oil entrained in the dephenolized weak liquor is recovered periodically by pumping off the accumulated layer floating on the stored liquor. Light oil dissolved in the dephenolized weak liquor is recovered during the treatment of the liquor in the ammonia concentration operation.

Decanters vs. Towers

In 1945, when the Wilputte Coke Oven Division was engaged in designing new facilities for the extension of the National Tube Company's coke plant at Lorain, Ohio, the existing phenol removal plant was studied closely. It appeared that the type of installation then in operation possessed definite economic merits. The study also provided the opportunity for designing another type of light oil absorption phenol removal plant whereby further reduction in capital investment could be obtained without sacrifice in removal efficiency and operating costs. Proceeding with the existing Lorain phenol plant as a basis, the Wilputte Coke Oven Division designed and installed the plant now in operation at Lorain. The essential difference between the Lorain and Ironton installations, apart from the final treatment and handling of the sodium phenolate, is in the substitution of a single packed tower in place of the mixing pump and decanter arrangement used for the absorption of phenol. Results in elimination have shown that the efficiencies obtained in these installations do not differ, proving that by proper evaluation of all factors involved installations for treatment of phenol-bearing waste effluents from coke plants can be readily designed and constructed.

NATIONAL TUBE CO., LORAIN, OHIO

By N. B. Thompson

Assistant Superintendent, Coke Plant

Experiments were started at the Lorain works of National Tube Company in 1920 to determine the most efficient and economical method of removing phenol from the by-product coke wastes. The two main sources of

phenol contamination were found to come from the cooling water leaving the benzol final coolers and from the waste liquor leaving the ammonia stills.

The final cooler cooling water was accordingly designed and placed in operation as a closed system. This included pumps and an atmospheric cooling tower. Any surplus condensate from this system was allowed to overflow to a coke quenching station.

A phenol recovery plant was designed and placed in operation in August, 1924, for the removal of phenol from the ammonia still wastes. The benzol recovery method was used, the plant being so designed that all the weak ammonia liquor must pass through the phenol plant before entering the ammonia still.

Recovery Process

The present phenol recovery plant consists of a scrubber 10 ft. in diameter and 65 ft. high. The grid packing is constructed of rough sawed wood slats. The benzol enters the bottom of the scrubber and is distributed through 2-in. perforated extra heavy steel pipe. The weak ammonia liquor enters at the top and is distributed through similar perforated pipe.

At the Lorain coke works the weak ammonia liquor, as condensed from the raw coke oven gas, contains 0.075 per cent phenol by weight. This liquor is pumped from a storage tank, through automatic stone filters to remove any traces of tar and insoluble material, to the top distributing pipes of the scrubber. Benzol flows continuously, in a volume equal to the weak liquor volume, to the bottom distributing pipes of the scrubber.

The phenol is extracted from the weak liquor by the benzol as they flow countercurrently through the scrubber. The average extraction over a 20-year period is 95.46 per cent.

The dephenolized weak liquor leaves the bottom of the scrubber through an adjustable overflow and is returned to a storage tank adjacent to the ammonia still. The phenolized benzol flows by gravity from the top of the ammonia scrubber to the caustic washer.

The caustic washer, 12 ft. in diameter and 60 ft. high, is constructed with four sections. The top section, known as the sulfur scrubber, removes some hydrogen sulfide, carbon dioxide, and other impurities from the benzol by means of a water wash.

The benzol then flows through the next two sections, connected in series and containing 20 per cent caustic solution. When the solution in the first washer is completely converted to sodium phenolate, it is removed, the solution from the second washer is transferred to the first washer, and a fresh 20 per cent caustic solution is run into the second washer.

The bottom section of the caustic washer acts as a storage or surge tank for the now dephenolized benzol. From this section it is pumped to the base of the ammonia scrubber, thus completing the cycle. Some benzol is carried in the dephenolized liquor to the ammonia still. This is returned to the coke oven gas stream with the ammonia gas and recovered in the benzol plant scrubbers.

The sodium phenolate is passed through a centrifuge to remove any benzol, together with any tar acids and naphthalene that may be dissolved in the benzol. A short rectification with direct steam follows the centrifuging, after which the sodium phenolate is treated in an agitator with 66° Baumé sulfuric acid.

At the completion of this springing process, the crude phenol floats on the solution of sodium sulfate. The sodium sulfate solution is drained to a recovery sump and the crude phenol to a storage tank for shipment. A typical sample of the crude phenol contains: phenol, 40.56 per cent; cresol, 33.45 per cent; and residue and wastes, 25.99 per cent.

DESIGN AND OPERATION OF A TREATMENT PLANT FOR PENICILLIN AND STREPTOMYCIN WASTES *

By A. A. Hilgart

Staff Engineer, Upjohn Company, Kalamazoo, Mich.

In the summer of 1945, when the Upjohn Company decided to build a plant for the production of penicillin and streptomycin, one of the first considerations was the matter of waste disposal. The manufacturing plant was to be located approximately six miles south of Kalamazoo, Mich., with the wastes treatment plant about 1,500 ft. west of the plant, and 4,500 ft. east of Portage Creek, which was to receive the treatment plant effluent.

The creek, a small stream having an estimated sustained flow of about 10 to 20 cu. ft. per sec., is in good condition, being used for recreational purposes about three miles downstream from the proposed location of the waste disposal plant. The character of the stream called for a complete treatment plant with an effluent containing no more than 100 lb. of 5-day B.O.D. per day, which required a B.O.D. reduction of better than 90 per cent.

Nature of Wastes

In the manufacture of penicillin, a mash consisting of corn steep liquor, lactose, and inorganic salts is fermented with a penicillin-producing mold. At the end of the fermentation period the mold is removed by filtration. The broth is then acidified and the penicillin removed by extraction in amyl acetate. The latter solution is in turn extracted with a buffered salt solution, and the penicillin is further purified by extraction into and out of a second solvent. As all solvents in the process are removed by distillation for re-use, the principal disposal problems involve the mold and the penicillin-extracted mash.

Pilot plant operations had been under way for some time in a plant in downtown Kalamazoo. An analysis of the wastes from this plant showed the B.O.D. in the penicillin-free wastes to be very high, averaging around 13,000 p.p.m. In an occasional spoiled batch the B.O.D. would be in excess of 30,000 p.p.m. Streptomycin wastes were much lower in strength, averaging 2,500 p.p.m. of 5-day B.O.D. Total suspended solids in the filtered beer ran about 400 p.p.m., with spoiled batch containing as high as 20,000 p.p.m. The pH of the wastes leaving the extraction units was between 2 and 3, but this was raised to 7.4 to 7.9 by the lye in the wash water used in cleaning up the equipment after harvesting the tanks. The filter cake solids (mycelium) has approximately 70 per cent moisture, and it was planned to bury this mold, which decomposes very rapidly under ordinary temperatures and must be disposed of at once to avoid very disagreeable odors.

In 1945, the available information on the treatment of penicillin wastes was very meager, and although it was known that these wastes could be successfully treated by biological processes, it was decided to undertake laboratory investigations to determine more closely the rate at which these wastes would digest, and provide a more secure basis for the design of the treatment plant. These experiments, conducted under the direction of F. W.

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Mohlman, director of laboratories of the Sanitary District of Chicago, extended over a period of almost four months from December, 1945, to March, 1946.

No attempt is made here to go into detail regarding the laboratory experiments, other than to say that six series of trickling filter tests, and seven series of digestion experiments were made. The best results in the trickling filter tests were obtained by aeration for 4 hr. and dilution with 4 parts of water before application to the trickling filters, giving a removal of 96 per cent with single-stage application at the rate of 1,450 lb. per acre-ft. Anaerobic digestion proved to be very unsuccessful with the penicillin wastes. Gas production was either entirely lacking or very low, and what was produced apparently contained very little methane.

The final basis of design, as determined from the results of the experiments, included a maximum flow rate of 700,000 g.p.d., including sanitary wastes from an employee population of 1,500 and a residential population of 2,500, and a total 5-day B.O.D., based on all penicillin production and sanitary wastes, of 3,060 lb. per day.

Plant Structures

The principal structures (see Figure 1) were:

1. Two 25,000-gal. capacity holding tanks for penicillin wastes and wash water, equipped with spargers for aeration and providing at least a 10-hr. retention period. These tanks were located adjacent to the manufacturing plant and aerated wastes were pumped periodically to the wastes treatment plant at the rate of 200 g.p.m.

2. Two 10-ft. deep preliminary sedimentation tanks having a displacement period of 2 hr. at a flow rate of 700,000 g.p.d. and a volume of 7,800 cu. ft.

3. Two 90-ft. diameter trickling filters, 6 ft. deep, having a unit load of 1,500 lb. per acre-ft. per 24 hr. The total volume of the filters is 1.73 acre-ft. and the area 0.288 acre. The filters are arranged for either series or parallel operations and, when used in series, for reversal of order of the two units. No intermediate sedimentation is provided between the first and second stage of series operation. Dilution is provided either by recirculating underflow from the final sedimentation tank or by the addition of cooling water from the storm drain to provide a constant 700,000-g.p.d. flow through the plant. The rate of application for parallel operation is 2.43 m.g.a.d., for series operation, 4.86 or 2.43 m.g.a.d.

4. Final sedimentation tanks consist of two units 8 ft. deep, having a 2-hr. displacement period at 700,000 g.p.d. and a 7,800-cu. ft. volume.

5. A chlorine contact tank with a 20-min. displacement period at the 700,000 g.p.d. rate.

6. One sludge digestion tank of 15,000-cu. ft. capacity.

7. Open sludge drying beds of 3,000-sq. ft. area.

The capacities of the various units were higher in some instances than those deemed sufficient by the results of the laboratory tests, and were increased at the suggestion of the Michigan Department of Health, which suggested that the retention period of both the primary and final sedimentation tanks be increased from 1½ hr. to 2 hr., and the displacement period of the contact tank be increased from 10 min. to 20 min. In addition, the sludge digester capacity was doubled (from 7,500 cu. ft. to 15,000 cu. ft.).

Subsequent operation of the plant proved the soundness of this advice, particularly with reference to the digester. All the laboratory tests indicated that very little sludge would be produced from the reduction of penicillin wastes and that the additional digester capacity would be required only when the residential population became tributary to the disposal plant.

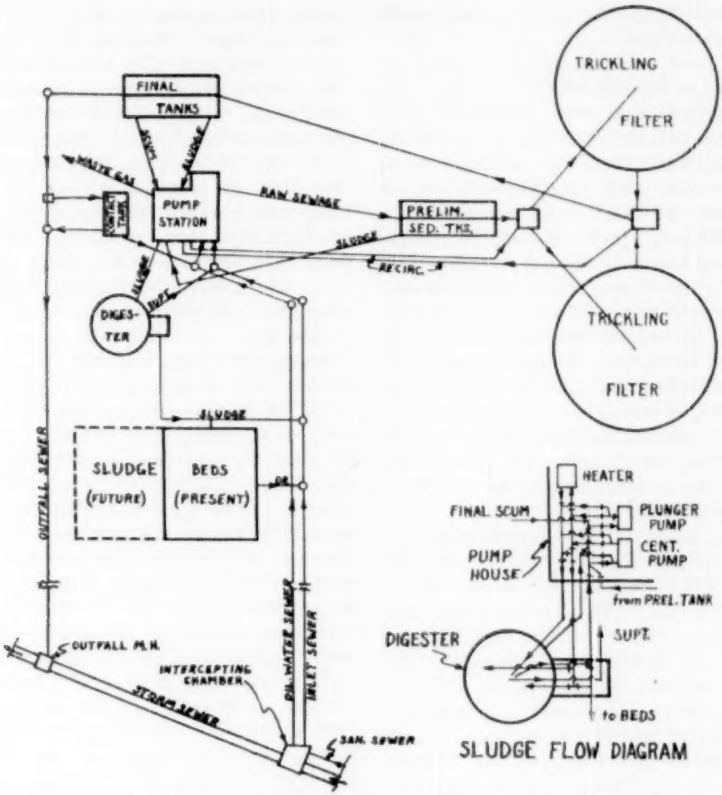

FIGURE 1.—Layout and sludge flow diagram of treatment plant for penicillin and streptomycin wastes.

Another suggestion incorporated in the design of the plant was the installation of scum troughs in the final sedimentation tanks. The added cost was very slight, but they have been used on frequent occasions.

Operating Problems

The wastes treatment plant was placed in operation in the spring of 1948, with the usual adjustments and corrections incidental to starting up a new plant being encountered. Among these was adjustment of the erratic operation of the 200 g.p.m. pump at the holding tank, which pumped raw sewage to the wastes treatment plant. The pumping cycle of 30 min. every 4 hr., as originally set up, delivered a shock load to the trickling filters. The most satisfactory pumping rate was found to be 8 min. out of each 30 min., which evened out the rate of flow and showed considerable improvement in the treatment of the wastes.

From time to time evidence of a heavy oil emulsion is apparent on the filter stones. This is caused by the lard oil used as an anti-foam agent in the fermenters. The emulsion gradually clogs the filters, but is sloughed off during the light loadings on the filters over the week-end. Additional grease trap capacity is under consider-

ation to keep this oil out of the wastes treatment plant.

Several odor complaints were received in the late summer of 1948. At that time they were attributed principally to the rather high concentration of amyl acetate in the wastes, due to the fact that the stripping still for the recovery of this solvent was not yet in operation. By November, odor complaints began to come in earnest—and with good reason. The odor of decomposing organic matter was very evident and was caused by incompletely digested sludge on the drying beds, incombustible gas discharged through the waste gas burner of the digester, and partly digested sewage applied to the trickling filters. The cause of odor from all these sources could be traced directly to the digester.

The sludge in the digester was in a stage of acid digestion, as indicated by the 6.0 pH of the supernatant liquor and the high CO_2, low methane, and high H_2S content of the digester gas. The CO_2 content was 63 per cent; the CH_4 content, 23 per cent; and the H_2S content, 2 per cent. Although the acid condition of the digester is not unusual before the onset of normal methane digestion, the disturbing element in this case was the excessive time required to overcome acid digestion. Six months had elapsed since the plant was placed in full operation. In the meantime, the digester had been filled and it became necessary to draw undigested sludge to the drying beds. In addition, an incombustible gas with a high H_2S content was being diffused into the atmosphere and supernatant liquor containing a high percentage of partly decomposed sludge and other soluble odor producing substance was being recirculated through the system.

The first of the measures taken to correct this very undesirable condition was to raise the pH of the digester to 7.2 or higher by the addition of hydrated lime, and to maintain this pH until methane digestion was established. The next step in odor control was to burn the gas being generated in the digester by enriching it with bottled propane gas until enough methane was produced to support combustion. This was done by tapping the line to the waste gas burner. To discourage the production of odors from the drying beds, they were sprayed with an emulsion of orthodichlorbenzene, which effectively disposed of the hydrogen sulfide odors.

Sludge from the digester had been hauled away in tank trucks at the rate of 30,000 gal. per month during August, September, and October. This practice was continued until well after the digester transferred to normal digestion. During the liming period very little sludge was pumped to the digester and raw sludge was hauled away from the primary tank during the subsequent winter months. The peak was reached in December, 1948 when 110,000 gal. were hauled. Normal pH was established by late December and a gas analysis taken in April, 1949 showed that the digester is functioning normally—methane was 70.3 per cent, CO_2 was 26.7 per cent, and H_2S was 0.1 per cent. With these corrective measures, all complaints of obnoxious odors subsided for a time.

Changes in Waste Character

Late in December, 1948 a number of samples of raw wastes were analyzed to determine if changes had taken place in the character of the wastes since the original investigation on which the treatment plant design was based. These analyses indicated a somewhat higher B.O.D. and a very marked increase in suspended solids, both total and volatile, amounting to better than 300 per cent for the total suspended solids and 500 per cent for the volatile solids. The implications of this increase in B.O.D. and suspended solids

and their effect on the disposal plant is now being studied, but no definite conclusions can be drawn at this time.

Another source of heavy solids loading on the filters is the occasional spoiled batch of penicillin containing suspended solids approximating 20,000 p.p.m. In the original design, these wastes were to be filtered before discharge to the treatment plant. However, subsequent operations proved that they were too heavy to pass through the filter. Such loads are relatively infrequent and none have been received for the past two months.

The filter aid used in the second-stage filtering of the penicillin is an inorganic diatomaceous earth, which settles very rapidly and in time is liable to compact in the digester and cause serious loss of capacity in the unit if these solids are not kept out of the wastes. In the plant described, the spent filter aid is carefully removed from the filter and hauled away with the mold and, except for a small quantity present in the wash water, does not appear in the wastes going to the treatment plant.

Conclusions

From experiences at this plant it can be concluded that these wastes can be successfully treated by biological processes. There have been extended periods when B.O.D. removal was as high as 97 per cent and total B.O.D. in the effluent discharged to the stream was less than 60 lb. per day. It can also be concluded that laboratory experiments are at best merely a guide in the design of a wastes treatment plant and that they do not take into account the modifications in manufacturing processes when full scale operations get underway. The large increase in solids in the penicillin wastes, as well as the higher 5-day B.O.D., indicate a solids loading approximately four times greater than that anticipated in the design of the plant. As a result the changes in operating procedure, plant design, or both, are presently under intensive investigation.

ACID IRON WASTES NEUTRALIZATION*

By Richard D. Hoak

Senior Fellow, Mellon Institute, Pittsburgh, Pa.

Spent pickle liquor, an acid iron waste produced by the steel industry, is essentially a solution of ferrous sulfate and sulfuric acid. A large number of processes have been proposed for recovering values from this industrial waste, but many factors have prevented their successful operation. Only copperas (ferrous sulfate heptahydrate) is recovered commercially, and conversion of about 4 per cent of the pickle liquor produced annually in this country supplies the market demand. In the majority of cases, therefore, the liquor must be neutralized to avoid pollution of streams.

Design Factors

Neutralization is costly, not only by virtue of the alkaline material required, but also because the sludge produced in the process must be disposed of; under some circumstances the cost of sludge disposal may greatly exceed the primary expense of neutralization. It is imperative that the most economical neutralization procedure be adopted, and a final decision should not be made until all significant factors have been investigated (3). Important considerations are the cost, reactivity, and availability of alkaline agents; the space available for the neutralization plant and for sludge storage; the anticipated volume and composition of pickle liquor and of rinse water; the pickling shop operating schedule; neutralization techniques; provision for discharge of effluent; and constructional details. Local conditions will sometimes impose other factors, but those given are the principal ones that should be taken into account in the preliminary investigation.

In general, certain factors will be fixed by conditions in the pickling shop. Operating schedules are usually rather inflexible, and the volume of pickle liquor will be governed by the kind of stock being cleaned. Similarly, it is necessary to comply with the requirements of public health departments applicable to the stream or municipal sewer into which the effluent is to be discharged. It is often possible to control some seemingly invariable factors. For example, an excessive volume of rinse water is used in many pickling operations; any reduction in volume from this source would obviously result in decreasing the size of a neutralization plant, as well as its cost of operation. It is important to seek ways to improve the efficiency of the pickling operation, because wasteful use of acid constitutes a double loss: the wasted acid must be neutralized. It is not always clearly recognized that the place to begin waste treatment is in the manufacturing plant itself.

Some latitude is available in the choice of a neutralization process, and it is necessary to exercise good judgment in selecting a process because it will usually be found that one technique will fit a given set of local conditions better than any other. Adoption of the proper plant will be influenced by the neutralizing agent, the neutralizing procedure, and sludge disposal facilities.

* Presented at 23rd Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cleveland, Ohio; June 22–24, 1949.

Selection of Neutralization Agent

It is not always sound economy to use the cheapest alkaline agent at hand, because delivered cost per ton can be a misleading criterion of neutralizing value. A potential neutralizing agent should be evaluated in terms of available alkalinity and reactivity, and the material should be held to specifications. Table I lists a number of possible agents and compares their cost in terms of dollars per ton of basicity.

High calcium quicklime is widely used for pickle liquor neutralization because of its general availability and high reactivity. It has been taken as the basic material for comparing costs in Table I. Dolomitic limestone was included in the table as an example of a cheap neutralizing agent that cannot be used for the purpose because of its extremely low reactivity.

Reaction Rate

The reaction rates of neutralizing agents cover a considerable range, and this factor will govern the size of the reaction tank. Where the treatment plant must be confined to a limited space, the most reactive agents are indicated. Conversely, where relatively long periods of time elapse between bulk discharges of liquor from the pickling shop, or where adequate space can be assigned for the treatment plant, one of the less reactive, but cheaper, materials, such as pulverized high-calcium limestone, may be used to advantage.

Reactivities of a variety of neutralizing agents are compared in Table II under various combinations of conditions. The liquor used in making the comparisons contained 60 grams of iron and 200 grams of sulfate ion per liter. In each case, a 5 per cent excess of alkaline agent was added. The data show the amount of iron unprecipitated after a 6-hr. reaction period, except where iron was absent in a shorter time.

Sludge Volume

The settleability and the final volume of the sludge are important where lagoon space is limited. If a lagoon cannot be provided, a new neutralization technique, described later, offers a solution to the problem. The settling rates of the sludges from Table II are shown in Table III. Values are given, for each of the reaction conditions, which show the initial settling rate and the final sludge volume, in percentage per minute and percentage of original sludge volume, respectively. In some cases, the sludge compacted to its final volume in a few hours; in others several days were required.

Characteristics of Various Agents

Every neutralization plant will differ from another in some respect, on ac-

TABLE I.—Cost Comparison of Various Alkaline Agents

Agent	Grade	Container	Price[a] ($/ton)	Basicity Factor[b]	Cost ($/ton of basicity)	Relative Cost
Sodium hydroxide	Flake, 76%	Drums	69.00	0.687	100.44	7.00
Sodium carbonate	Dense, 58%	Barrels	40.00	0.507	78.89	5.43
Magnesium oxide	Calcined	Cartons	64.00	1.306	49.00	3.41
High-calcium hydrate	Chemical	Bags	13.50	0.710	19.01	1.32
Dolomitic hydrate	Chemical	Bags	13.50	0.912	14.80	1.03
High-calcium quicklime	Pulverized	Bulk	13.50	0.941	14.35	1.00
Dolomitic quicklime	Ground	Bulk	11.00	1.110	9.91	0.69
High-calcium limestone	Pulverized	Bulk	3.75	0.489	7.67	0.53
Dolomitic limestone	Pulverized	Bulk	3.20	0.564	5.67	0.39

[a] Current quotations, June 1, 1949, in carload lots.
[b] Grams equivalent CaO per gram.

TABLE II.—Reactivity of Alkaline Agents with Pickle Liquor
(Iron unprecipitated after 6 hours, grams per liter)

Agent	Conditions of Reaction			
	Room Temp.	60° C.	Room Temp.	60° C.
	No Aeration (1)	No Aeration (2)	With Aeration (3)	With Aeration (4)
NaOH	—[1]	—[1]	—[1]	—[1]
Na_2CO_3	0 in 0.75 hr.	0 in 0.75 hr.	0 in 0.75 hr.	0 in 0.5 hr.
MgO[2]	0 in 3 hr.	0.72	0 in 0.5 hr.	0 in 0.25 hr.
MgO[3]	14.08	14.08	11.99	2.50
CaO	0 in 0.25 hr.	0 in 0.25 hr.	0 in 5 min.	0 in 5 min.
CaO·MgO	1.88	3.14	1.04	0.30
$Ca(OH)_2$	0 in 0.5 hr.	0 in 0.5 hr.	0 in 0.5 hr.	0 in 0.5 hr.
$Ca(OH)_2$·MgO	1.23	1.53	0.55	0 in 3.5 hr.
Acetylene sludge[4]	1.66	1.04	0 in 3.5 hr.	0 in 3.5 hr.
Cement dust[2]	9.44	8.02	2.43	0 in 4 hr.
Cement dust[3]	13.81	14.00	8.02	3.49
$CaCO_3$, precipitated	8.95	5.17	0 in 2 hr.	0 in 1.5 hr.
$CaCO_3$, limestone	20.40	18.80	2.95	0.03

[1] Reaction practically instantaneous.
[2] Reactive.
[3] Unreactive.
[4] $Ca(OH)_2$.

count of local conditions. Selection of the proper alkaline agent may be the determining factor in the final plant design. In this section the significant characteristics of the most likely agents are discussed in detail.

TABLE III.—Sludge Settleability

Agent	Conditions of Reaction[1]							
	1		2		3		4	
	Initial Rate[2]	Final Volume[3]	Initial Rate[2]	Final Volume[3]	Initial Rate[2]	Final Volume[3]	Initial Rate[2]	Final Volume[3]
NaOH	0.03	83	0.04	79	0.03	84	0.00	96
Na_2CO_3	4.4	16	3.6	22	5.6	14	2.4	20
MgO[4]	0.22	58	0.55	44	0.18	44	0.00	100
MgO[5]	—[6]	—[6]	—[6]	—[6]	—[6]	—[6]	1.33	11
CaO	0.01	91	0.07	69	0.01	92	0.01	81
CaO·MgO	0.00	100	0.10	70	0.05	51	0.05	57
$Ca(OH)_2$	0.07	68	0.13	70	0.01	93	0.03	95
$Ca(OH)_2$·MgO	0.03	71	0.10	57	0.67	48	0.00	60
Acetylene sludge	0.13	75	0.27	69	0.67	70	0.27	80
Cement dust[4]	1.73	62	1.33	58	1.26	70	1.24	67
Cement dust[5]	—[6]	—[6]	—[6]	—[6]	—[6]	—[6]	—[6]	—[6]
$CaCO_3$, precipitated	0.67	63	0.63	65	0.13	72	0.2	57
$CaCO_3$, limestone	—[6]	—[6]	—[6]	—[6]	0.57	46	0.13	77

[1] See headings of Table I.
[2] In per cent per minute.
[3] In per cent of original attained in 17 to 20 hr.
[4] Reactive.
[5] Unreactive.
[6] Settling rate meaningless because of small fraction of iron precipitated.

Caustic Soda

Caustic soda is the most reactive of the common agents, but its high price will normally preclude its use in all but exceptional circumstances. It has, however, certain definite advantages that must be weighed in reaching a decision. Its high reactivity and the small volume of sludge it yields, where the reaction is carried out near the boiling point, means that plant size will be small per unit volume of pickle liquor. In addition, the relatively pure hydrated iron oxide can be recovered and sintered for blast-furnace charge, and pure sodium sulfate, either anhydrous or Glauber salt, can be produced from the iron-free supernatant. These recoveries will partly offset its high price, as will the compactness of the plant itself.

Mills which use caustic soda degreasing baths, or have sodium hydride pickling installations, should investigate such sources of caustic for possible application in a pickle liquor neutralization plant. Also, the possibility of obtaining relatively impure by-product caustic, either as a solid or as a moderately dilute solution, from a nearby chemical plant should be explored to reduce over-all operating costs.

Soda Ash

Soda ash is not only costly, but much less reactive than caustic soda. It would appear to have no place in the pickle liquor neutralization field, except where only the free acid needs to be neutralized. Ease of handling offers an advantage in this case.

Ammonia

In addition to being high in price, ammonia will not precipitate iron completely because of the formation of a soluble iron-ammonia complex. Special equipment is required to realize the full effectiveness of ammonia, and its use is uneconomical except under special conditions in large mills.

High-Calcium Lime

The high reactivity and low cost of both high-calcium quicklime and hydrate point to these compounds as the most universally desirable agents for pickle liquor treatment. For full effectiveness quicklime must be properly slaked and the hydrate thoroughly wetted before use. These materials have been dealt with in detail in another paper (1).

The supply of high-calcium limes is limited in some areas. It is reported, however, that the available supply is generally adequate to accommodate the pickle liquor neutralization plants whose construction is anticipated.

Dolomitic Lime

Less reactive than the equivalent high-calcium products, dolomitic quicklime and hydrate are in somewhat better supply. These products have higher basicities than their high-calcium counterparts, and, as they sell for approximately the same price, provide basicity at a lower unit cost. Low reactivity is the principal objection to dolomitic materials, but this disadvantage can be overcome by adoption of proper techniques (2).

Aeration of the reaction mixture is the most effective means of reducing the time for complete iron removal with dolomitic lime. Table IV shows the effect of aeration on a pickle liquor treated with dolomitic lime at room

TABLE IV.—Effect of Aeration

Time (hr.)	Unaerated		Aerated	
	Fe (gm./l.)	pH	Fe (gm./l.)	pH
0.083	4.71	6.9	4.15	5.1
0.25	3.15	7.1	2.88	4.8
0.5	2.46	7.0	2.53	4.2
1	1.90	7.0	1.12	2.7
2	1.40	6.9	0.08	4.2
3	1.40	7.0	—	—
5	1.18	7.1	—	—
6	0.56	7.5	—	—

temperature. These data reveal that oxidation has little effect in the early stages of the reaction, but as the rate of iron precipitation decreases the oxidation rate increases relatively faster than the rate of iron precipitation, reduces the pH of the mixture, and provides the driving force for completion of the reaction, by increasing the tendency of the alkaline agent to dissolve.

Pulverized High-Calcium Limestone

Pulverized high-calcium limestone is a cheap agent that is usually in plentiful supply. Unfortunately, however, its reactivity is low. Moreover, the reactivities of limestones from different sources vary widely, and a stone should be selected only after making comparisons in trial neutralizations. Dolomitic limestone is too unreactive for pickle liquor treatment.

There probably are a number of localities where one of the more reactive limestones will provide economical complete treatment. This would normally be the case where the volume of pickle liquor is small and ample reaction time can be provided. The split limestone-lime method (1) has demonstrated operating economies in commercial practice.

Precipitated Chalk

Precipitated chalk, being more reactive than natural calcium carbonate, and selling at only a slightly higher price where it is a by-product of chemical manufacture, may find expansible uses for neutralization.

Cement Dust

Experimental work on cement dust, a by-product of portland cement manufacture, was limited to two samples from different sources. Its reactivity varies considerably and would appear to be generally similar to that of pulverized high-calcium limestone. It should be available at a low price. It is unlikely that this material could be employed for complete treatment of pickle liquor because of its low reaction rate, but where a reactive dust is available at low cost it could be used as a primary agent if aeration and heat could be provided.

Acetylene Sludge

Acetylene sludge, a trade waste from acetylene generation, is an impure hydrated high-calcium lime which is available in many areas at a low price. Being less reactive toward pickle liquor than high-calcium hydrate, this material could be used successfully in a split treatment.

Magnesia

The rather high price of magnesia limits its value as a neutralizing agent. Nevertheless, its high basicity, and the possibility it offers for recovering pure iron oxide and magnesium sulfate, would reduce its net cost. It might find a useful application in areas where there is a steady demand for magnesium sulfate. Commercial magnesias vary in reactivity, depending on the method of manufacture.

The Neutralization Process

A number of neutralization procedures have been developed to fill existing needs. These should be studied to determine the one process that will best fit local conditions. The reaction tank should be constructed of appropriate acid-resistant material and equipped with any type of agitator that will provide thorough mixing. The spent liquor and alkaline agent may be added to the reaction vessel by any suitable means, and the resultant slurry may be pumped, or discharged by gravity, to a storage lagoon. Handling and application of lime have been dealt with comprehensively by Rudolfs (6).

Conventional Neutralization

This technique is practiced almost universally where pickle liquor is treated with an alkaline agent. It comprises mixing the proper amount

of agent with the liquor until the reaction is complete. In this treatment it is important that quicklime is properly slaked (or hydrate wetted) for maximum efficiency in utilizing the agent.

Split Treatment

In localities where pulverized high-calcium limestone or a similar low-cost agent can be purchased at a relatively low price per ton of equivalent calcium oxide, economies can be realized by employing a split treatment (1), in which the limestone is used to neutralize the free acid and precipitate the ferric fraction of the iron, and a more reactive (but more costly) agent is used to complete the treatment. The proportion of the treatment borne by each agent will be determined by local conditions. If both compounds were pure, it would be economical to substitute pulverized stone for quicklime where the former could be bought for less than 56 per cent of the price of the latter. In practice, the break-even point is about 61 per cent. It must be emphasized here that dolomitic limestone is unsuitable for this application.

Polishing Treatment

Where a cheap but relatively unreactive agent is available, operating schedules or limited space for the neutralization plant usually prevent its use because of the relatively long time required to complete the reaction. In a case of this kind it is possible to obtain much of the economy of the cheap agent by using it to perform the major proportion of the neutralization and a more reactive material to complete the treatment. This technique is similar to the split treatment; but here the primary agent is required to do a much larger part of the job, and the secondary agent becomes, more accurately, a polishing agent (3).

Pulverized high-calcium limestone, precipitated chalk, dolomitic quicklime or hydrate, and cement dust may be cited as examples of possible primary agents. Sometimes a survey of the region in which the plant is located will disclose an enterprise that produces a suitable alkaline material as a waste product. Such sources often yield a satisfactory agent that may be had for little more than the cost of transportation.

Polishing agents comprise a group of very reactive alkaline materials that can be used without serious handling problems and whose cost is not excessively high. Caustic soda, high-calcium quicklime, and high-calcium hydrate are examples of suitable polishers. Soda ash, which would appear to be suitable, cannot be used effectively because it will not readily produce a sufficiently high pH (9.3) for complete precipitation of ferrous iron. Heat and aeration are necessary to remove the carbon dioxide formed by the soda ash reaction, and this adds to the operating cost. In addition, it is substantially less reactive than the other agents cited.

Excess Agent Method

C. J. Lewis has developed a neutralization process (5) which yields a final slurry that can be dewatered in a centrifuge. The process involves adding a large excess (300 to 400 per cent) of dry alkaline agent to pickle liquor while the mixture is stirred thoroughly. The excess agent has the property of converting the slurry into a granular mass that can be dewatered centrifugally. Where the waste water must be completely free of suspended solids it is necessary to pass the centrifuge effluent through a polishing filter. This process is applicable only where a relatively small volume (2,000 to 3,000 g.p.d.) of pickle liquor is to be treated, because of the cost of the neutralizing agent.

New Neutralization Technique

The author and his co-workers have developed a new method (4) for neu-

tralizing pickle liquor that provides a solution to the problem of sludge disposal where limited or no lagoon space is available. The process depends on controlled oxidation of the iron, in the presence of an alkaline agent, to ferrosoferric oxide. It is simple to operate, consisting only of feeding pickle liquor at a predetermined constant rate to a bath in a reactor, where the temperature is maintained above 75° C. and means are provided for efficient aeration.

Variables were evaluated in a pilot plant reactor illustrated diagrammatically in Figure 1. It consisted of a

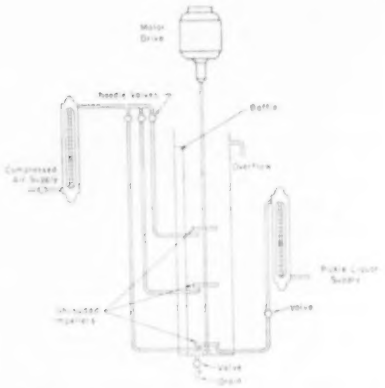

FIGURE 1.—Schematic arrangement of pilot plant apparatus for pickle liquor neutralization.

section of steel pipe bolted to a steel base. Aeration was supplied by three shrouded impellers, mounted equidistant on a shaft, with a separate air supply for each. The impellers were driven at a peripheral speed of 700 ft. per min. A vertical baffle, extending the full depth of the reactor, furnished necessary turbulence. Waste pickle liquor was admitted from a reservoir through a tube discharging below the lowermost impeller. Details of the reactor design are presented in Figure 2.

All the runs reported here were made by the cyclic continuous method because suitable equipment was not available for feeding the alkaline agents accurately at a sufficiently constant rate to collect data on continuous operation. Supplemental runs, in which the alkaline agent was added manually, revealed that with proper feeding devices the process could be operated continuously without difficulty. Magnesia, dolomitic quicklime, and high-calcium quicklime were evaluated by this process; the operating procedure was the same for each agent.

For each run, a quantity of alkaline agent equivalent to or somewhat in excess of the stoichiometric requirement of 8 liters of pickle liquor was slaked in water and mixed thoroughly with about 8 liters of slurry left in the reactor from a previous run. The mixture was heated externally to the proper temperature, and the air feed set at the desired rate. The three needle valves were adjusted to split the air feed into three substantially equal streams. The pickle liquor feed was then started at a predetermined rate. Pickle liquor was fed to the bath at a constant rate until 8 liters had been added. A sample of slurry was then filtered, and the filtrate tested for soluble iron; if iron was present, the air feed was continued until the iron oxidized and was precipitated. Where the variables were properly adjusted, all the iron was precipitated at the end of the pickle liquor feed period. Half of the slurry in the reactor was then drained off, and that remaining was used immediately to start another cycle. Although the characteristics of the sludge produced in succeeding cycles was affected to some extent by the quality of the slurry present at the start of a run, this effect was normally small, even when the variables were changed over a relatively broad range.

The successful operation of the process depends primarily on balancing the rate of iron precipitation with the rate of oxidation of ferrous hydrate. These rates must be so controlled that the iron

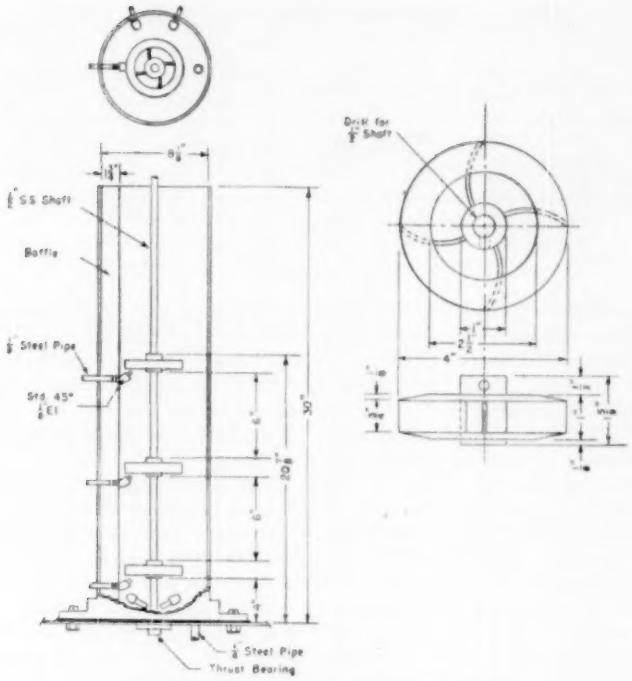

FIGURE 2.—Details of reactor design.

in the precipitate will have a ferric to ferrous ratio between 2 and 5, preferably between 2.5 and 3.5, while the temperature of the bath is maintained high enough to promote the formation of ferrosoferric oxide. Obviously, there are many variables that should be considered in selecting the optimum operating conditions—for example: reactor design, including aeration and agitation; reactivity of alkaline agent; composition of pickle liquor; reaction temperature; excess alkaline agent; and pickle liquor and air feed rates.

Detailed study of each of these variables would be an undertaking of considerable magnitude. Fortunately, all are not of equal importance. Experiments have demonstrated that reactor design is not a critical factor, except that efficient dispersion of air must be provided. Although shrouded turbines were used in this study, a turbomixer gave satisfactory results in a trial run, and there is no reason why any of the aerator-agitator devices on the market that provide vigorous dispersion of air could not be used. The lower temperature limit is governed by the conditions for formation of ferrosoferric oxide. Choice of alkaline agent and composition of liquor will be fixed by local conditions. In a commercial installation, then, the only variables to be decided on would be excess agent and the rate of feed of pickle liquor and air. These could easily be established by a few trial runs.

The data presented show the feasibility of the process and the improvement in sludge properties that may be expected from it. Magnesia was used to develop the basic principles of the process to avoid interference from

TABLE V.—Neutralization of Pickle Liquor with Several Agents

Agent	Liquor	Agent (% of reqmt.)	Liquor Rate (ml./min.)	Temp. (°C.)	Slurry pH	Fe^{+++}/Fe^{++}	Fe in Supernatant (g./l.)	Initial Settling (in./min.)	Final Sludge Vol. (% of orig.)
MgO	Weak	105	270	80	6.9	3.36	0.03	0.85	8
MgO	Strong	104.5	117	80	7.4	2.69	0.04	0.53	16
CaO-MgO	Weak	110	108	84	8.0	3.45	0.01	0.76	20.5
CaO-MgO	Strong	110	75	82	6.9	2.53	0.02	0.60	30
CaO	Weak	105	285	79	9.0	2.53	0.00	0.58	35
CaO	Strong	105	140	82	9.5	2.50	0.00	0.40	58

other compounds, such as calcium sulfate. High-calcium lime was then studied because of its popularity as a neutralizing agent, and also because there was considerable doubt that it could be adapted to the process in view of the amount of calcium sulfate that would be coprecipitated. Finally, dolomitic lime was used to represent a neutralizing agent whose reactivity was intermediate between that of the first two materials investigated. Actually, the dolomitic lime was found to be less reactive than the magnesia employed in the study, but the magnesia chosen was the chemical grade, a highly reactive form of the compound.

The pickle liquor used was made by dissolving steel mill copperas and sulfuric acid in water to yield a solution containing 60 grams of iron and 200 grams of sulfate per liter; this composition was chosen to represent the waste liquor from continuous strip picklers. For each alkaline agent studied a series of runs was made with the standard liquor diluted with an equal volume of water. Another series was then made with the full-strength liquor. This procedure was adopted primarily to facilitate the process development, but it served also to illustrate the conditions to be expected where the waste liquor is combined with rinse water.

A representative set of data is given in Table V. Actually, more than 100 runs were made with the experimental plant, it being invariably possible to duplicate results for a given set of conditions.

The most significant feature of the new process is the rapid rate of slurry subsidence; under normal conditions settling is complete in 15 to 30 min. In addition, the smallest practicable final sludge volume is achieved by this technique.

The slurry can be filtered at a high rate on a vacuum filter. For example, the slurry from a high-calcium lime neutralization can be filtered at a rate of over 400 lb. of wet cake per square foot per hour, and the cake will contain 60 per cent dry solids. This filtration rate is about twenty times as high as can be obtained with slurry from a conventional neutralization. The high rate can be explained by the fact that the coprecipitated calcium sulfate crystallizes in long needles, which act as a filter aid. In fact, filtration rate is proportional to the amount of calcium sulfate in the slurry.

This technique has been described in some detail because it is so new that no commercial installations have yet been made, although several are in prospect. Operation is quite simple; temperature and ferric-ferrous ratio are the only critical variables, and these are readily controllable.

Summary

This paper has presented in outline the principal factors that must be considered in designing a plant for waste pickle liquor neutralization. The principles set forth should be applicable to most problems in acid waste treatment. The importance of choosing the proper

alkaline agent has been emphasized, as well as the advantage to be gained by utilizing circumstances peculiar to a given locality. A new neutralization technique, which is a considerable advance in the art, has been presented to offer a solution to the problem of sludge disposal where lagoons cannot be installed.

Acknowledgment

This work was undertaken as a part of the research program of the Stream Pollution Committee of the American Iron and Steel Institute, through the Multiple Industrial Fellowship it has sustained at Mellon Institute since 1938.

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NEW BEET SUGAR WASTES TREATMENT PROCESS

A new treatment process for beet sugar wastes that combines the advantages of increased sugar yield and elimination of an important source of stream pollution, has been announced by Clair N. Sawyer, associate professor of sanitary chemistry at Massachusetts Institute of Technology. Developed under Professor Sawyer's direction by E. A. Pearson, now of the University of California, the new waste treatment increases the yield of sugar by about 4 lb. per ton of beets, while reducing water consumption by at least 320 gal. Thus, a source of pollution involving annually about 3,000 m.g. of waste water would be eliminated.

Under the new method, a very small amount of chlorine is dissolved in the mill's process waste water to destroy bacteria and make possible rapid separation of the non-sugar impurities. The small concentration of valuable sugar remaining in the water can then be recovered, as the treated water may be re-used for sugar extraction, instead of being discharged as waste. The resulting reduction in water requirements (about 30 per cent) promises to become an important aid in protecting and conserving water supplies in sugar beet areas.

Preliminary economic studies are reported to indicate that savings during the first year of operation should pay the cost of the necessary new treating equipment.

AN ACID IRON WASTES NEUTRALIZATION PLANT*

By Roy F. Lab

Chief Chemist, Copperweld Steel Co., Warren, Ohio

After trying several makeshift methods for disposal of waste pickle acid, Copperweld Steel Company in January, 1944, put into service the neutralization equipment now in use at its Warren, Ohio, plant. The treatment plant has functioned in a satisfactory manner and consists of the following units (see Figure 1):

1. A bucket elevator for unloading hopper cars into an overhead lime bin holding 150,000 lb. of hydrated lime (the contents of two hopper cars).

2. A hopper scale of 3,000-lb. capacity, beneath the lime bin and over a 3,000-gal. tank for mixing lime slurry.

3. An open pit or well attached to the building containing the lime bin, etc., and in which the waste pickle acid is accumulated after it is discharged from the pickle tanks as being spent. This tank is of concrete lined with acid-proof brick, is 23½ ft. square and 13 ft. deep, and holds about 50,000 gal.

4. A neutralizing tower attached to the other side of the building. This is also of concrete lined with acid-proof brick, is 18 ft. high and 10 ft. in diameter, and holds 10,000 gal.

5. A lagoon 400 ft. square, originally 9 ft. deep, and located in a field about 2,000 ft. removed from the rest of the plant. Here final effluent is discharged, the sludge settles, and clear liquid overflows into the Mahoning River.

6. Two duriron acid pumps in the basement of the building proper, and two sludge pumps in a lean-to adjoining the building.

In operation, lime is received in hopper cars and unloaded by bucket elevator into the lime storage bin. Waste pickle acid and wash water from pickle tanks is accumulated in the well at the neutralizing plant. A 5,000-gal. batch of the waste pickle acid is pumped into the neutralizing tank and mixed by recirculating for 5 min. A sample is then drawn off and checked for acid and iron content. Given the acid and iron content, the operator determines from a chart the amount of lime necessary for neutralization. This amount of lime is weighed and dropped into 2,000 gal. of water in the lime mixing tank, the mixture being agitated with motor driven paddles to a smooth slurry. The slurry is then pumped into the neutralizing tank, which already contains 5,000 gal. of waste acid.

After the lime water and acid have been mixed by recirculation for 45 min., a sample is withdrawn and the pH determined. If the pH is 9 or over the neutralized acid mixture is discharged to the settling pond and another batch is started. If the pH is under 9.0 more lime is added and the agitation is continued until the pH is 9.0 or over. An operator can process five batches per 8-hr. day.

Lime required per batch will vary from as little as 100 to 200 lb. to as much as 3,500 lb., depending on the concentration of acid and iron in the waste being treated. In the operation described, dolomitic hydrated lime is used because it is found to be uniformly fine and consistent. Consequently, maintenance costs of handling equipment and pumps are fairly low. It

* Presented at 23rd Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cleveland, Ohio; June 22–24, 1949.

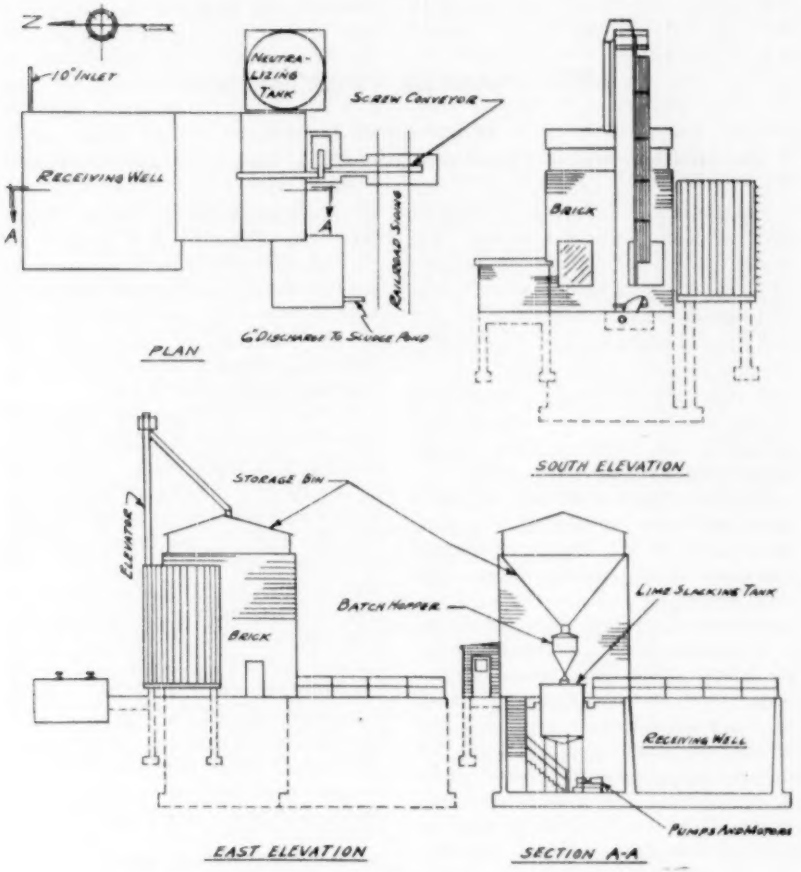

FIGURE 1.—Layout of acid iron wastes neutralization plant.

has been found that in using approximately 5,000 gal. of waste acid per batch, 650 lb. of lime are required for each per cent of iron plus acid. It has been found also that about a ton of lime must be purchased for each ton of acid bought.

When 1,000 lb. or more of lime are required for a given batch of waste acid a colloidal activator is used with the lime. Much more consistent results are obtained by using 1 lb. of activator per 800 lb. of lime than by using lime alone.

Although this equipment and method of disposal is satisfactory, it is expected that the next few years will yield developments that will improve the method and minimize some of the more serious problems connected with it. One of these is the elimination of the sludge pond. A continuous filter or centrifuge to separate the sludge from the liquid, so that the sludge can be transported to a suitable place in a railroad car, will be a big step in making waste acid neutralization less of a problem to most steel plants.

ACID WASTES TREATMENT *

By Edward M. Jones

Superintendent, Chemical Engineering Dept., Tennessee Copper Co., Copperhill, Tenn.

Inorganic acid wastes are one of the more common industrial wastes. The report of the Ohio River Committee (1) lists the acid wastes of the states of Kentucky and Tennessee at 237,225 and 131,038 tons per year, respectively, the figures representing $CaCO_3$ equivalent tons. The total load to the streams of the Ohio River basin is estimated at 1,864,000 tons $CaCO_3$ equivalent, and the principal source is coal mines.

The acid waste treatment activities described herein are selected from some experiences of the Tennessee Copper Company, at Copperhill, Tenn. The acid wastes have their origin in the operations associated with the large-scale manufacture of sulfuric acid from the heavy sulfide ores mined in this area, known as the Ducktown Basin. The operations include the mining of the ore, its treatment by flotation for the separation and concentration of its mineral content, the roasting and sintering of the iron sulfide mineral to produce iron sinter product and SO_2 gas for the acid plants, and the production of sulfuric acid from the SO_2 gas. In each of these multiple operations there are problems of waste disposal and treatment, and because of the sulfur content of the materials handled the wastes are of an acid character. The wastes discharged from these operations are neutralized with ground dolomitic limestone, the neutralized effluents being discharged into three creeks emptying into the Ocoee River, which in turn empties into the Tennessee River about 40 mi. below Copperhill. The situation is a general one with similar plants producing sulfuric acid by the so-called metallurgical-type acid process. The first installation of a specific neutralizing plant for the Tennessee Copper Company's operation was constructed in 1916.

In recent years, beginning just before World War II, a number of major changes have taken place. Production of the major products has greatly increased and the increase in acid production has been by the contact process, due to changed market demands. The contact process of the metallurgical type creates more acid wastes than the older chamber plant process. These changes have thus made acid waste treatment a major problem. Waste treatment practices of the past have been continued with few changes until very recent years and have been unsuitable from both the standpoint of stream pollution control and economy.

Research Program

Consequently, a definite program of research and investigation was started in 1943 to provide a solution for the whole problem. The program was, at the start, necessarily aimed at the correction of the most obvious waste sources.

For this problem, as for any other industrial waste, there were three main lines of attack:

1. Elimination or reduction of waste.
2. Recovery or utilization.
3. Treatment or, in this case, neutralization.

Some success has been achieved in all three lines.

* Presented at 1949 Annual Meeting, Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.; Lexington, Ky.; Oct. 31-Nov. 2, 1949.

A great deal has been accomplished in the way of reduction of wastes. One development is particularly outstanding. In the standard practice of roasting sulfide ores, some 5 to 7 per cent of the sulfur burned off is converted into SO_2, which is necessarily lost as weak acid in scrubbing and cleaning the gas. This constituted one of the major sources of acid waste. As the result of considerable research and experimentation a major modification of the conventional roaster was devised and put into operation, and with this improvement the SO_2 loss has been reduced to 2 per cent. There is reason for belief that it may be reduced below this. This development, along with others not so outstanding, has enabled us to maintain our over-all loss of sulfur in waste effluents slightly over the prewar level, while at the same time the production level has nearly doubled.

The cases of waste reduction accomplished simply by locating them and bringing them to someone's attention for remedy are not recounted. It is so easy and natural for operating personnel, who are interested in the production angle, to take the attitude that another little waste will make no difference.

It has been the objective of this research program to arrive at a comprehensive plan for the reduction of wastes and an efficient and economical treatment plant.

Wastes Surveys

Over-all surveys have been made at various times, and have been followed by detailed investigations of the individual sources. The data obtained included flow rates, chemical composition, acid concentration, and temperatures, along with a study of the operation responsible for the waste. Such investigations covered enough time to find the variations and establish maximum and minimum rates.

Little success has been achieved along the line of utilization of the acid wastes. Unfortunately for the case of waste recovery, sulfuric acid is a low-price commodity and little can be done with wastes containing generally less than 1 per cent H_2SO_4. In two cases it was possible to find a use for a portion of a very minor effluent containing 1.5 per cent H_2SO_4.

In the gas cleaning system of the contact plants there are waste effluents containing appreciable quantities of dissolved sulfur dioxide (SO_2). This gas, when dissolved in water, constitutes sulfurous acid; a weak acid, but a very difficult one to deal with. It undergoes rather rapid oxidation to sulfuric acid. At one of the plants, a stripping tower was built to recover this dissolved gas. The tower was built without too much known about the process involved, but in 1948 a detailed study was made of the process and tower performance. From this data a new tower is being designed to remove the SO_2 from this effluent and recover it in a usable condition.

The two general solutions of the problem—elimination and recovery—offer the most advantageous means for waste treatment, in that they offer opportunities for some economic returns, and give the most satisfactory answer to waste control. However, a large percentage of the total waste remains to be treated and it is in this third line of endeavor that the most immediate interest undoubtedly lies.

Neutralization

A study was made of the possibilities of using various available neutralizing agents, both as to their effectiveness and ultimate cost. For obvious cost considerations, the materials tested were limited to burned or hydrated limes and limestones. There was no question that the use of some form of quicklime would constitute an effective and satisfactory neutralizing material, but if used exclusively, would be pro-

hibitive from a cost standpoint. The limestones tested were of both high-calcium and dolomitic types available within a reasonable freight distance in Tennessee and Georgia.

The results obtained as to the relative reactivity of high-calcium and dolomitic limestone were in general agreement with data reported by Hoak, Lewis, and Hodge (2) and by Jacobs (3), in that the dolomite is slower than the high-calcium type in reacting with acid. There were exceptions to this, as one dolomite was found that was superior to some of the high-calcium limestones. It was concluded that the magnesium content was not a definite indication of lack of reactivity, it being evident that the crystal structure had a marked effect in this respect.

The limestone finally selected contains 54 per cent calcium carbonate and 37 per cent magnesium carbonate. As received, the material will pass a 35-mesh screen, with approximately 40 per cent being retained on a 200-mesh screen. The comparisons as to reactivity referred to above were made on similar screen sizes.

More recently, a study has been made of various factors involved in the rate of reaction between sulfuric acid and limestone, for the purpose of designing a neutralizing plant that will perform as required. The factors investigated were strength of acid, screen size of the limestone, reaction temperature, and the effect of various excess percentages of limestone. Additional work on the effects of iron salts and dissolved SO_2 has not been completed.

As to the effect of acid strength in the range from 100 to 5,000 p.p.m., the rate of reaction, as pounds of acid neutralized per hour, was found to be proportional to the concentration of acid. It was therefore advantageous to use undiluted effluents to achieve rapid consumption of the limestone. At strengths somewhat above 5,000 p.p.m. insoluble calcium sulfate can form and effectively coat the particles of limestone so that the reaction is inhibited. For this reason, dolomitic limestone can be more effective than high-calcium limestone in the higher acid concentrations.

For these tests 1-l. samples were used of acid solutions of different strengths, to which was added the exact equivalent of limestone, as determined by its ultimate neutralizing value. The reaction was allowed to proceed in a constant temperature bath, and all samples were stirred at the same rate and with duplicate stirring mechanisms. Readings were taken with a pH meter throughout the period of reaction and small samples were periodically withdrawn by pipette, rapidly filtered, and titrated for acidity to pH 7.0. The limestone used was the standard limestone screened to pass a 200-mesh screen.

Particle Size and Temperature

For the study of the effect of particle size, the limestone was carefully screened and the fractions retained on the 200, 270, 325, 400, and the minus 400 screens were used, along with a sample of the unscreened limestone as received. The acid neutralizing value of each fraction was determined, and equivalent weights based on these values were reacted with identical quantities and concentrations of acid.

A very low rate was found for the plus-200-mesh material. The unscreened material had the next higher rate, and the finer sizes had considerably higher rates. For the fine sizes, the rates did not all correspond with fineness. This was interpreted to mean that there was a difference in structure of the crystals in the different sizes, evidently related to the phenomenon of critical particle sizes referred to by Hoak, Lewis, and Hodge (2).

Starting with the assumption that the rate of reaction was directly proportional to the strength of acid and to the area of the limestone particles in contact with acid, a differential equa-

tion was set up expressing this relationship, and a plot of the experimental results was compared to the integrated form of the equation. A fair correlation was obtained on individual particle sizes, but poor correlation was secured between different particle sizes.

Translating this information on the effect of particle size into practice a wet ball mill has been installed at the Copperhill plant to reduce further the particle size of the limestone used so that 95 per cent will pass a 200-mesh screen. Improved neutralization has resulted. A second installation at the Isabella plant has been approved for installation. There is a further advantage to the finer particle size in that it remains in suspension much more readily in the present neutralizing equipment (tanks and flumes).

To evaluate the effect of temperature, similar tests were made, but with varying temperatures from 100° to 140° F., covering the range expected in acid effluents. There was a decided increase in the rate of reaction at the higher temperature, as would be expected.

The use of excess limestone materially improved the reaction rate, particularly as the reaction approached neutrality. It is, in fact, impossible to obtain complete neutralization with only the theoretical quantity of limestone.

The work on the effects of dissolved SO_2 and iron salts is not completed, but it can be stated that SO_2 shows practically a zero reaction rate with limestone, and is neutralized only after it has been oxidized to sulfuric acid. The effect of iron is to slow up the reaction as measured by the pH.

The over-all conclusion from this study is that the waste effluents can be satisfactorily neutralized with the dolomitic limestone in 1.25 hr. reaction time.

Further Studies

There remains one further possible modification of the limestone treatment that has received some study—the possibility of a finishing treatment with burned lime. The treatment offers several advantages in decreased time of neutralization and in the simplicity of control, but has the great disadvantages of double treatment and higher cost material for neutralization. The final conclusion on this can be made only the basis of further experience and a thorough consideration of the economics involved.

The information outlined above was secured for the specific purpose of designing neutralizing equipment to replace the miscellaneous and inefficient apparatus now in use, and to provide centralized operation at each of the two plant locations.

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TREATMENT OF CYANIDE WASTES FROM THE ELECTROPLATING INDUSTRY *

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Abatement of stream pollution on a national as well as a local basis is attracting increasing attention, both of the general public and industry alike. Seldom can one pick up a newspaper or magazine without seeing articles on pollution problems or pollution control. It has often been said that much of the adverse publicity would not be forthcoming if it were not for the unusual instances that occur, such as odor nuisances, fish killings, etc. At the same time, nothing so obviously indicates the necessity for pollution control.

Although these "unusual instances" cannot be attributed to any one particular type or source of waste, a look at the record will show that some types of wastes do offend more often than others. For instance, in a 3-year period prior to December, 1948, there are on record in the files of the Michigan Water Resources Commission 56 instances where extensive fish mortality has occurred. In 19 cases the cause was definitely traced to cyanide; in another four, cyanide was strongly suspected. In 10 cases the cause was attributed to sewage and industrial wastes, and in 9 cases the cause was undetermined. From that point, the summary tapers down to 3 or 4 cases for various causes. Therefore, of the 47 cases where the cause was definitely determined, almost half (49 per cent) were traceable to cyanide wastes.

In addition to the destruction of aquatic life, cyanide wastes have frequently menaced public and private water supplies, and agricultural interests have been damaged by loss of livestock after drinking from cyanide-bearing streams. Where the wastes enter municipal sewage plants the treatment processes have been impaired, thereby causing an inferior quality of effluent and indirectly bringing about additional pollution.

Toxicity of Cyanide

Free cyanide is one of the most toxic substances found in industrial effluents. Several investigations have been made in an effort to determine its effect on fish life, but the results of these investigations are not always in agreement, mostly because the effect of several variable factors (such as dissolved oxygen, temperature, pH, and the presence or absence of other ions in the test solutions) have been overlooked. From the available data it appears that 0.1 p.p.m. cyanide as CN generally would be fatal to fish, although under certain conditions this limit may be reduced to as little as 0.05 p.p.m. (1). An average of 60 mg. is generally fatal to animals and humans.

Although cyanide exerts a toxic effect on sewage purification processes, it appears that higher concentrations of cyanide are permissible in sewage plants than in streams. It is not likely that cyanide would cause any difficulty in a sewage plant utilizing sedimentation and sludge incineration, although there would undoubtedly be an increase in the chlorine demand of the sewage. On the other hand, where

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sludge digestion is substituted for incineration considerable difficulty may be experienced. Ridenour (2), in experiments conducted at the University of Michigan, studied the effect of sodium cyanide on sludge digestion and concluded that initial charges of 3.0 p.p.m. NaCN exerted a toxic effect, but "acclimatization" of the digesting sludges allowed greatly increased doses (up to 30 p.p.m. over a 30-day period) without seriously impairing the volume or quality of gas production as measured by CO_2 and H_2S production.

Eldridge (3) reports that the addition of 25 p.p.m. KCN to sewage sludge had little effect on digestion, whereas the addition of 50 to 100 p.p.m. exerted an inhibiting effect for several days. These experiments were made batch-wise and no conclusions can be drawn as to the effect of continuous cyanide application.

It should be pointed out that these experiments were made with pure simple cyanides, and that plating wastes, in addition to their cyanide content, will contain varying quantities of metals, many of which are inhibitors in the digestion of sewage sludge.

If a cyanide waste is to be discharged to a treatment plant employing biological processes it is generally advisable to maintain the CN concentration below 1 to 2 p.p.m. Ridenour (4) reports that 2 to 3 p.p.m. NaCN exerts an inhibiting effect on nitrification in the activated sludge process, although nitrification was not completely destroyed with waste additions up to 40 p.p.m. In all cases the process returned to normal two days after the additions of waste were stopped.

Trickling filters likewise have a low tolerance for cyanide, although it has been demonstrated that trickling filters can become acclimatized to high concentrations of cyanide and that when acclimatized are capable of producing a satisfactory effluent from the standpoint of both CN and B.O.D. reduction. However, because filters require considerable time to become acclimatized it does not appear wise to rely on this property in considering what concentration of cyanide can be permitted in a treatment plant (5). Both types of biological treatment are sensitive to slight changes in CN concentration and any sudden surges of strong cyanide may result in a complete collapse of the treatment system.

Sources of Waste

Cyanide compounds are among the most widely used industrial chemicals and are a constituent of many industrial wastes. However, there are seven processes which are the sources of most of the cyanide wastes causing serious stream pollution and creating problems in sewage plant operation. These processes are:

1. The plating of metals.
2. Case hardening of steel.
3. Neutralization of acid pickle scum.
4. The refining of gold and silver ores.
5. The scrubbing of blast furnace and producer gas furnace gases.
6. Coke ovens.
7. Surface cleaning of various metals.

Because of the primary interest in wastes from the metal plating industry, and because the case hardening of steel is sometimes closely allied with metal plating—often both processes are done in the same plant—a brief description of both processes follows.

Plating of Metals

Metal plating is essentially an electrochemical process by which an article fabricated of some common base metal can be coated with another tightly adherent metal that possesses certain desirable physical or chemical characteristics (6). Metals commonly used for plating are copper, chromium, zinc,

cadmium, nickel, and the precious metals, gold and silver.

The usual plating room contains a series of vats in which are cleaning, plating, and washing solutions. The metal parts to be plated are moved from one vat to another either individually or on racks containing a number of parts. The movement of work from one vat to another may be either by hand or by automatic conveyors. The operations in a typical plating process may include any or all of the following:

1. Degreasing with organic solvents or vapors.
2. Scale removal by pickling in a suitable acid.
3. Electrolytic cleaning.
4. Plating operations.
5. Water rinses where necessary.

Wastes from the plating room arise from two sources: First, a continuous waste consisting of the overflows from the hot or cold rinse waters following the various operations; and second, the intermittent wastes or batch dumps of concentrated solutions.

The continuous waste discharges will be found to contain varying amounts of all the solutions used in the plating process, the amount of polluting materials or "dragout" depending on the volume of rinse water used, the mechanics of the plating operation, and the type and amount of work being plated. Rinse waters have been known to contain as high as 500 p.p.m. cyanide as KCN, although others have been found that contain as little as 1 or 2 p.p.m.

The intermittent wastes have been found to be the most important cause of pollution. These wastes consist of the routine batch dumps of spent, spoiled, obsolete, or otherwise unusable baths used in the surface preparation and plating of the metals. Sometimes these dumps may be the result of accident rather than an operational routine. Generally, the expense of replacing electrolytes is great enough so that considerable effort is made to restore them to use by filtering out impurities and then bringing the bath back to normal strength by addition of the proper chemicals. However, in all too many cases these baths are discharged to the sewer without any precautionary measures.

Case Hardening of Steel

The process of heat treating steel by cyanide consists of immersing the part in a molten salt bath high in sodium cyanide content for a predetermined period of time. After removal from the molten bath the work is quenched in either oil or a running water rinse. The cyanide content of these rinse waters will run as high as 50 to 100 p.p.m. as free cyanide.

In addition to the quench waters, there is also a problem of disposing of the spent salts. The practice sometimes employed of hauling the ash to a dump should be discontinued, as it becomes accessible to humans or animals and may leach into the ground water or nearby streams. Treatment of wastes from the heat-treating process is easier than the treatment of plating wastes because only simple cyanides are present.

Waste Control Measures

In attempting to solve a particular pollution problem one of the first steps should be a study to determine the amounts and variations in concentration and volume of waste leaving the plant each day. The necessary data can easily be obtained by the installation of weirs or other flow measuring devices, along with a continuous sampling mechanism that will take a small sample every few minutes throughout the work period. Laboratory analyses of the composited sample will then determine the amount of materials being lost to the plant sewer.

If laboratory analyses indicate excessive quantities of plating solutions

are being lost, a concerted effort should be made to reduce the amount by making simple changes in operating techniques. For instance, a good reclaim program will do more to reduce a pollution problem than any other single measure. The substitution of a dip tank for a rinse immediately following the plating bath will markedly reduce the amount of electrolyte being lost to the sewer by dragout, the solution so collected being utilized by return to the bath for make-up. In some systems, especially those where evaporation losses are low or where dragin is equal to dragout, it is obviously more difficult to operate a dip reclaim. In these cases one of two steps can be taken: (1) the amount of dragin can be reduced by vibrating the work or by use of an air blow-off; or (2) the reclaimed solution can be partially evaporated in special evaporators.

Another procedure that will serve not only to simplify a pollution problem, but also to eliminate the possibility of high concentrations of plating solutions getting into the sewer, is to maintain a separation of the weak wastes from the strong wastes by constructing separate drainage systems for each. The drainage system for the weak wash and rinse waters would consist of a system of piping connected only to those tanks from which dilute rinse waters flow. In some cases these dilute wastes could be discharged without treatment or be given a simpler treatment than a mixture of the strong wastes would require.

The drainage system for the strong wastes would consist of a system of floor drains, so located as to serve each tank containing concentrated solutions. Tanks, piping, and filtering equipment should be surrounded by adequate curbing to catch all spills, breaks, or other unavoidable accidents that would permit the sudden release of large quantities of solution. The floor drains should in no way be connected to the regular sewer system, but instead should be connected to a sump or holding tank of a capacity equal to 1½ times the combined capacity of the tanks within the curbed area. Disposal or treatment of any accumulated wastes should be under the direct supervision of a responsible employee designated by the management.

The advantages of a good waste control program, as differentiated from a waste treatment program, cannot be too strongly emphasized. Examples have been found in many industries where waste control has eliminated the need for waste treatment, or at least has materially reduced the extent to which it must be carried. It is, therefore, sound practice to explore and apply every advantage of control in the solution of a problem.

Disposal of Cyanide Wastes

Disposal by Dilution

Perhaps the simplest method for the disposal of plating wastes is to dump them into the nearest stream. There are few platers who have not at some time or other, either of necessity or by accident, disposed of large batches of plating solutions in this manner. In the past, the disposal of concentrated baths by dilution has been grossly abused, usually because there has been a lack of understanding or a failure to recognize the limitations that the method offers. For example, the disposal of 5,000 gal. of a spoiled plating solution containing 3 oz. per gal. NaCN would require 600 m.g. of diluting water (120,000 gal. of dilution water per gallon of solution) to reduce the CN concentration to a value that could be tolerated by fish life. Although the receiving stream might furnish such volumes, proper control would have to be maintained at all times to prevent local high concentrations—and such control is not easy to insure. Other factors, such as the condition of the stream in respect to pH, temperature, dissolved oxygen, and the

degree of upstream regulation, further complicate this method of disposal. In short, dilution can only be considered a satisfactory method for disposing of this highly toxic waste under exceptional circumstances.

Disposal by Ponding

Where ample land is available, the use of impounding reservoirs appears to be the cheapest and simplest method of plating waste disposal. Such ponds should be constructed with no overflow to a stream, and should receive only the concentrated wastes and first rinses. Also, they should be of adequate capacity so that the losses through seepage and evaporation are either equal to or greater than the amount of inflow, and must be situated away from any sources of water supply. Seepage into the ground presents a definite hazard, through pollution of ground water, that must not be overlooked where this method is to be used. Such ponds must also be protected to prevent access by either humans or animals.

The chemical changes by which cyanide is reduced in a pond system are not thoroughly understood, although several explanations have been offered. In the absence of acid conditions it appears likely that the main reaction depends on the absorption of carbon dioxide from the atmosphere to convert the cyanide to HCN, which in turn is given off as a gas. There is also the possibility of various oxidation and hydrolysis reactions, but these reactions are considered to be of minor importance (7).

The rate of cyanide reduction of an impounded waste depends to a considerable extent on the pH of the wastes, the depth of liquid within the ponds, the temperature, and the air pressure. Loss of cyanide from alkaline wastes is very slow, whereas in slightly acid solutions the loss is reasonably rapid. Wise (8) reports that with a pond depth of 2 ft., a waste of pH 3.0 and containing 100 p.p.m. cyanide was reduced to 5 p.p.m. in 48 hours.

Disadvantages in the use of ponds for cyanide waste disposal are: The large areas of land needed in order to handle large volumes of waste; the risk of polluting ground waters; and the danger of dike breaks. On the other hand, the method offers the advantages of simplicity and cheapness of operation, providing the land is available.

At best, ponding is only the next step better than discharge direct to a stream, and should be considered only as a temporary measure pending more positive means of control.

Treatment of Cyanide Wastes

In the last 35 or 40 years several ingenious methods have been developed for the recovery or destruction of cyanide from industrial process wastes. In the early years attention mostly was given to the recovery of cyanide from mining or gas works wastes; many patents covering these processes have been granted both in the U. S. and other countries. In an ideal waste treatment system the recovery of by-products at a profit is a distinct economic advantage. However, not all cyanide-bearing wastes are of such nature as to make recovery profitable, and at the present time it appears that electroplating wastes fall into this classification.

Some work has been done toward the recovery of metals, especially the precious metals, but generally speaking, the recovery of cyanide does not appear to be economical. Furthermore, few of the cyanide recovery processes produce an effluent that would provide acceptable pollution control, and with increasing attention being focused on stream pollution, recent efforts in the field of plating waste treatment have been directed toward the destruction of the cyanide ion, thereby permitting the resulting effluent to be

discharged to a water course or sewage system without detrimental effect.

In this paper no attempt has been made to classify or evaluate all known methods of cyanide waste treatment, but only to present those methods most commonly used or available to the industry.

Treatment with Sulfuric Acid

The conversion of cyanide to the volatile HCN gas through the use of sulfuric acid has proved to be an effective means of treatment. The facilities required consist of an air-tight holding tank, lead or rubber lined or otherwise treated to prevent corrosion, and equipped with a vent stack and air blower. In practice, the spent solutions are collected in the tank, sulfuric acid is added to reduce the pH below 4.0, and the contents are agitated by blowing air through the solution. Sometimes steam is used to hasten the reaction. The soluble cyanide is volatilized to hydrogen cyanide, which is blown to the atmosphere through the vent stack. A sludge containing the insoluble cyanides precipitates in the bottom of the tank, and the supernatant liquor is bled slowly to the receiving stream or outlet. The method is applicable to both the strong rinses and the concentrated batch dumps.

Two plants in Michigan—namely, the Chevrolet Division of the General Motors Corporation at Flint, and the Kaiser-Fraser Corporation at Willow Run—have successfully operated installations using this method for a number of years. The Chevrolet installation consisted of a rubber-lined tank of 4,600-gal. capacity, fitted with an air-tight cover and a 60-ft. stack with blower. Acid was added from a hopper and distributed through the tank in a perforated lead pipe. Operations at this plant consistently reduced concentrated copper cyanide plating solutions to 1.0 p.p.m. CN, or less (9). Although a solution of this strength would be toxic to fish if undiluted, only minor precautions would be necessary in discharging the waste to a stream.

The amount of acid required to react with any given plating solution will depend on the alkalinity of the solution and the cyanide content. To determine the amount necessary, Eldridge (10) suggests adding 10 per cent excess to the theoretical amount required to neutralize the alkalinity as $CaCO_3$ and react with the cyanide as KCN. No equation is given for determining the theoretical amount. Probably a simpler method of control would be to add enough acid to maintain the solution under pH 4.0.

The exact chemical changes that take place during the acid treatment of a cyanide waste are usually complicated and will vary considerably, depending on the presence or absence of certain ions. The important point to note is that not all of the cyanide in a plating solution is released as HCN by acid treatment.

In the past, considerable attention has been given to the danger resulting from the venting of HCN gas to the atmosphere, especially in populated areas. However, the danger from this source appears to be more imaginary than real. According to standards adopted by the Industrial Health Division of the Michigan Department of Health, the maximum allowable concentration of HCN in air for an 8-hr. working day is 10 p.p.m., although that of chlorine is given as 2 p.p.m. This does not imply that one should be careless with HCN, but merely emphasizes the point that chlorine, a common gas handled daily in most waterworks and sewage plants, is five times more toxic than HCN.

Alkaline-Chlorination

The oxidation of cyanide to cyanate, carbon dioxide, and nitrogen compounds under alkaline pH conditions is a method of treatment that has recently come into widespread use. The method is applicable to both concen-

trated baths and dilute rinse waters, and can be designed to operate on either a continuous flow or batch basis.

Many oxidizing agents (such as chlorine gas, hypochlorites, and bleaching powder) have been successfully used in the process, but the usefulness of bleaching powder and hypochlorites appears to be limited to small operations. Bleaching powder was found to produce excessive quantities of sludge. In addition, it presented mechanical difficulties in handling and mixing the large quantities of powder required for treating comparatively small volumes of waste (11). The use of hypochlorites somewhat reduces the magnitude of these difficulties, but it is considerably more expensive. On the other hand, chlorine gas is cheap, readily available, clean, and easy to handle and apply.

The chemical reaction that takes place when chlorine is added to an alkali-cyanide solution of pH 8.5 is almost instantaneous and results in the formation of cyanates, chlorides, and water according to the following reaction:

$$NaCN + 2\ NaOH + Cl_2 \rightarrow NaCNO + 2\ NaCl + H_2O$$

Theoretically it requires 2.73 parts of chlorine and 3.08 parts of caustic per part of cyanide, although in actual practice it may require more chlorine and less caustic depending on the composition of the waste.

Further oxidation of the cyanate to carbon dioxide and nitrogen compounds will occur if chlorine is added beyond the amount required for the first stage of the reaction, as follows:

$$2\ NaCNO + 4\ NaOH + 3\ Cl_2 \rightarrow 2\ CO_2 + 6\ NaCl + N_2 + 2\ H_2O$$

About twice as much chlorine is required for complete oxidation as is used in the first reaction (12).

At the high pH of this treatment method the metals present are precipitated as oxides, hydroxides, and carbonates. In plants using large quantities of metals, recovery may be feasible.

Maintenance of the solution to be treated at pH 8.5 or above is absolutely necessary for successful operation of this system. Failure to do so results in the formation of poisonous cyanogen chloride and nitrogen trichloride.

The design of a treatment plant for the oxidation of cyanide by chlorination will vary with each plant, depending on such factors as the volume and concentration of the wastes and the degree of variation of the volume and concentration. In any case, the separation of acid wastes from the caustic and cyanide wastes is a requisite.

For a small batch treatment plant, the equipment and structures needed would include a holding tank of adequate capacity to hold one day's flow, and equipped with a mixing mechanism; provision for the addition of either dry or liquid caustic; and a chlorinator from which a controlled amount of chlorine can be added. An installation designed on these general principles has recently been completed at the Kirsch Company plant at Sturgis, Mich.

In a plant designed to operate on a continuous flow basis it would be desirable to further separate the strong caustic and cyanide solutions from the weaker rinse waters, and to provide a holding tank equipped with a proportioning pump by which the strong wastes could be added to the weaker waste flow. By so doing, the fluctuation in waste concentrations can be materially reduced, thereby facilitating plant operation. Alkali, in either dry or liquid form, can be added to the combined wastes with the rate of feed controlled by an automatic pH mechanism, the electrodes of which should be located beyond the point of chlorination. The chlorine feed may be either manual or automatic depending on the variation in the volume and concentration of the waste. If the cyanide

is to be completely oxidized (to CO_2 and N_2 compounds) it would be necessary to add additional tank capacity to permit the reaction to be completed (about one hour).

Studies to determine the effect of alkaline-chlorinated plating solutions on sewage purification processes have recently been completed. These data indicate that although the treated wastes will exert a toxic effect on anaerobic sludge digestion and the activated sludge process, the concentrations necessary are extremely out of proportion to probable occurrence (13).

The toxicity of the treated solutions to fish life has been reported as being 1/600 to 1/800 as toxic as the untreated wastes. However, failure to obtain lower toxicity values in these particular tests is believed due to the presence of sodium chloride, cyanates, and free chlorine in the treated solutions (14).

Electrolytic Oxidation

The destruction of cyanide and the simultaneous plating out of some of the metals by the electrolysis of hot aqueous plating solutions is a method of treatment that has long been known to the industry, but has never gained widespread use. However, recent publicity given the method has created considerable interest.

The method offers the advantages (15) that:

1. It will convert CN to CNO.
2. Reclamation of metals is possible.
3. No sludge disposal problem is created.
4. The operator is using methods and equipment with which he is thoroughly familiar.

Disadvantages that are limiting factors in the use of the method (7) are:

1. It is applicable only to concentrated solutions.
2. Excessive time is required to reduce cyanide to permissible limits.
3. The cyanate content of an electrolytically treated solution may be of toxic concentration and may require further treatment.
4. It is difficult to find an electrode material that will give a reasonable life. (Several materials such as iron, lead, nickel, copper, steel, and graphite have been used, the choice of which depends on the solution to be treated.)

In practice, electrolytic destruction of cyanide entails the application of conditions opposite to accepted plating practices, such as high temperatures, air agitation, use of insoluble electrodes, high current densities, and high anode to cathode ratio.

Although the method has been occasionally used by various firms, operational data are relatively meager. Caldwell and Sperry (15) recently reported on the electrolytic oxidation of 700 gal. of a copper cyanide plating solution having an initial concentration of 2.84 oz. per gal. total cyanide and 2.10 oz. per gal. copper. The equipment used was that already available in the plating room. The following conditions were used for the test run:

Tank size: 10 ft. by 2.5 ft. by 4.0 ft. deep.
Generator: 5,000 amp., 6 v.
Electrode material: Steel.
Cathode area: 72 sq. ft.
Anode area: 72 sq. ft.
Agitation: By air hose, hourly.
Cathode area per gallon solution: 0.1 sq. ft.
Anode area per gallon solution: 0.1 sq. ft.
Average current density: 35 amp. per sq. ft.

At the end of 18 hr. the copper content had been reduced to zero and the cyanide content to about 1 oz. per gal. An additional 17 hr. was required for complete removal of the cyanide. On completion of the run, sulfuric acid was used to reduce the solution to pH 6.5, thereby destroying the cyanates and any minute amounts of cyanide

that might have been present. The solution was then dumped to the sewer.

The method holds definite promise for the destruction of strong plating solutions, especially in those cases where the treatment of the rinse waters is unnecessary.

Conversion of Cyanide to Thiocyanate

The use of calcium polysulfide, available commercially as common lime sulfur, for the conversion of cyanide to the less toxic thiocyanate is a method of treatment often recommended to the plating industry. In general, the process consists of the addition of an excess of lime sulfur (70 per cent calcium polysulfide) and heating the solution nearly to the boiling point. Early experimenters with the method reported that original concentrations of 20 to 1,000 p.p.m. NaCN in various waste solutions could be reduced to as little as 0.1 to 4.0 p.p.m. (16).

Dosages required are 0.43 gal. of lime sulfur solution (29.75 per cent calcium polysulfide) or 1.84 lb. of solid lime sulfur (70 per cent calcium polysulfide) per pound of sodium cyanide present. Reaction time is given as 2 hr. at room temperature, or 30 min. at boiling temperature (11).

However, more recent experiments indicate that the conversion of cyanide to thiocyanate is not always complete under the above conditions, with the result that the treated solution might still be highly toxic (17). Furthermore, the addition of acid will liberate hydrogen sulfide, which is not only malodorous, but also toxic in itself. Subsequent chlorination will also convert the thiocyanates to the highly toxic gases, hydrogen cyanide and cyanogen chloride.

Use of Ferrous Salts and Lime

The use of ferrous sulfate and lime for the removal of cyanide from plating room wastes is a method of treatment that has been used abroad, but has never gained widespread usage in the United States. In this process an excess of ferrous sulfate is added after adding sufficient lime to maintain the solution between pH 7.5 and 10.5. Insoluble complex cyanides of iron are formed and are removed by sedimentation. Southgate (18) reports cyanide removals to about 5 p.p.m., which makes the method useful for pretreatment of wastes that are to be discharged to comparatively large volumes of sewage for further treatment.

Reports from American investigators are not in agreement as to the results obtainable with this method. Some reports state that cyanide removals below 50 to 60 p.p.m. are not possible, although others claim removals up to 99 per cent from solutions originally containing 110 to 1,020 p.p.m. KCN (3) (19). Apparently there are several variable factors affecting the reactions involved that are not yet completely understood.

Assuming the method to be capable of adequate cyanide removals, its use would still be limited by the following disadvantages:

1. Accurate chemical control is required.
2. Excessive quantities of sludge are produced.
3. Discharge direct to a stream is prohibited because of the strong highly colored effluent. (Excess ferrous sulfate would be oxidized by oxygen in the stream and precipitated as ferric oxide.)

At the same time, the method offers the advantages of removing all metallic ions that might be present, and the chemicals used are fairly cheap.

From the available data it appears that this method of treating cyanide wastes might be useful in small shops, or for the pretreatment of wastes that are to be discharged to municipal sewage systems for further treatment.

Ion Exchange

Synthetic resin filters, such as those used for the demineralization or soften-

ing of water, have been tried experimentally on cyanide-bearing plating wastes. It is too early, however, to draw any definite conclusions as to the feasibility of the method. Furthermore, it should be pointed out that ion exchange is actually not a method of treatment, but only a method of concentrating wastes, which could then be treated by some known process, or possibly recovered.

Experimentally it has been shown that the removal of cyanide by anion exchangers alone is not possible, probably due to the near equality of the ionic weights of the cyanide and the hydroxyl ions (20). However, by using a cation and anion exchanger in series, it is possible to materially reduce the cyanide content of plating wastes.

Further investigation of the ion exchange method for reduction of cyanide wastes is necessary.

Summary

1. The uncontrolled discharges of untreated cyanide-bearing wastes from the electroplating and heat-treating processes have frequently menaced public water supplies, and resulted in damage to livestock, fish life, and municipal sewage treatment plants.

2. Several investigations have been made in an effort to determine the allowable cyanide concentrations in streams and sewage systems. It is generally conceded that concentrations exceeding 0.1 p.p.m. are harmful to fish and aquatic life, whereas the permissible concentrations in sewage plants are in the order of 1 to 3 p.p.m.

3. The plating waste disposal problem is usually complicated by an extreme variation in volume and concentration of the wastes, not only between plants, but within certain plants. Simplification of a problem is made possible by waste segregation and a good waste control program

4. Of the various methods of cyanide waste disposal, disposal by dilution has generally proved to offer inadequate protection. Ponding of cyanide wastes may have limited application, but should be considered only as a temporary measure pending more positive means of control.

5. Of the methods developed for treatment of cyanide wastes, acidification and aeration, or alkaline-chlorination offer the most flexibility and are applicable to almost any case. Electrolytic oxidation offers some advantages where it is necessary to treat concentrated wastes only. The use of ferrous salts and lime, or the lime-sulfur process may find limited application for small plants or where the wastes are to be further treated in sewage treatment plants. The use of ion exchangers for the concentration of cyanide needs further investigation before the method can be evaluated.

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Stream Pollution

RECENTLY ENACTED FEDERAL WATER POLLUTION CONTROL LEGISLATION *

By M. Le Bosquet, Jr.

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On June 30, 1948, the President signed Public Law 845, officially cited as the "Water Pollution Control Act." Since its enactment this Act has been discussed widely. Operating plans have been formulated. Appropriations of somewhat less than the full amount authorized have been approved, and this country's first nation-wide water pollution control program is underway.

Indications are, however, that certain phases of the legislation are not clearly understood in some circles. The objective of this discussion is to present a brief resume of the principal provisions of the Act, and to follow with a more detailed discussion of the comprehensive program, the financial provisions and regulatory features, the impact on and advantage to the states, interstate agencies, municipalities, and industries, and finally to outline recent activities.

Administration of Public Law 845 is divided between the Public Health Service (PHS) of the Federal Security Agency and the former Federal Works Agency, now known as the General Services Administration (GSA). Section 1 of the Act declares it (a) "to be the policy of Congress to recognize, preserve and protect the primary responsibilities and rights of the states in controlling water pollution"; (b) "to support and aid technical research to devise and perfect methods of treatment of industrial wastes"; (c) "to provide Federal technical services to state and interstate agencies, and to industries"; and (d) to provide "financial aid to State and interstate agencies and municipalities in the formulation and execution of their stream pollution abatement programs."

In support of this policy, the Act provides for surveys, investigations, and research. It provides for encouragement of uniform state laws and formation of interstate compacts. It provides for regulation of pollution on interstate waters with state consent, and for a Water Pollution Control Advisory Board, as well as containing a number of financial provisions for loans to construct remedial works, for grants to plan remedial works, and for grants to assist state regulatory bodies.

Comprehensive Program

Section 2 (a) of the Act provides that the Surgeon General shall, after investigation and cooperative activities, "prepare or adopt comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof." In preparing such programs, water uses to be considered include "public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural, industrial, and other legitimate uses."

Essentially these programs consist of a background presentation covering

* Presented at 23rd Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cleveland, Ohio; June 22–24, 1949.

such items as water uses, sources of pollution, water quality, and stream flow. From this basic presentation, the program contemplates "reasonable and equitable projects for the abatement of pollution." The desirability of approaching a pollution abatement program on the basis of an over-all river basin, or an over-all stream or section thereof, has generally been recognized. In many cases, pollution abatement projects are interdependent and a series of projects is required before full benefit can be realized from a pollution abatement program.

From a practical standpoint, the Act provides that before a loan may be secured, the project to be financed must be included "in a comprehensive program developed pursuant to this Act."

Financial Provisions

The financial authorizations of the Act, six in number, are for the fiscal years 1949 to 1953, inclusive. There is authorized to be appropriated to the Public Health Service, Federal Security Agency, for loans for remedial works, $22,500,000 per year; for grants to state and interstate agencies, $1,000,000 per year; and for all operating expense, including research, not to exceed $2,000,000 per year. There is authorized to be appropriated to the General Services Administration, for grants to states, municipalities, and interstate agencies for advance plans of remedial works, $1,000,000 per year; for all operating expense, not to exceed $500,000 per year; and for construction of a laboratory facility for Public Health Service use, $800,000 per year.

Loans for Construction

The authorization for loans for remedial works of $22,500,000 per year is for projects conforming to the following requirements:

1. The projects must be approved by the state water pollution control agency.

2. They must be approved by the Surgeon General.

3. They must be in the comprehensive program.

4. The loans are to be for $250,000 or 33⅓ per cent of the cost, whichever is smaller, are to be at 2 per cent interest, and secured by approved bonds. The loan can be subordinated to other bonds, as in a second mortgage.

Although the loan appropriation authorization is for the Federal Security Agency, the Act provides that funds shall be transferred to the General Services Administration on written request, specifying projects approved by the Surgeon General, the cost of such projects, and the total loans proposed. The loans are to be made in accordance with a priority list established by the Surgeon General.

An appropriation for carrying out the loan provisions of the Act was not passed by the 1949 session of Congress. For obvious reasons loan applications are not being accepted.

State and Interstate Agency Grants

Under Section 8 (a) of the Act, an appropriation of $1,000,000 per year is authorized for allotment to states and interstate agencies. The appropriation is to the Federal Security Agency and allotted by that agency for expenditure by or under the direction of the water pollution control agencies of the states or directly by interstate agencies. The purpose for which allotments are made is "the conduct of investigations, research, surveys, and studies relative to the prevention and control of water pollution caused by industrial wastes."

Planning Grants

Section 8 (c) of the Act authorizes $1,000,000 per year to be appropriated to the General Services Administration for grants to states, municipalities, and interstate agencies for the preparation of engineering studies, plans, and so

on, preliminary to the construction of remedial works. Individual grants can be $20,000 or 33⅓ per cent of preliminary costs, whichever is smaller. Projects for which grants are made require approval by the state and by the Surgeon General.

There are three more financial provisions in the Act. Section 8 (b) provides for the appropriation of funds for the erection and equipment of a building in Cincinnati for water pollution research and studies. The appropriation authorized is for the General Services Administration. Progress has been made in preparing plans for this building, and it is hoped that it can be completed in somewhat less than the five years indicated by the Act.

Section 8 (d) authorizes an annual appropriation of $2,000,000 per year to the Federal Security Agency to carry out its functions, and Section 8 (e) authorizes an annual appropriation of $500,000 to the General Services Administration to carry out its functions.

Current Appropriations

No appropriations were passed for the fiscal year ending June 30, 1949. The authorizations and the appropriations passed for the fiscal year ending June 30, 1950 are as follows:

Section	Purpose	Authorization Per Year	Appropriation for 1949–1950
7	Loans for remedial works	$22,500,000	None[1]
8-a	State and interstate grants	1,000,000	$1,000,000[2]
8-d	P.H.S. operations	2,000,000	1,200,000
8-c	Planning grants (G.S.A.)	1,000,000	200,000
8-e	G.S.A. operations	500,000	125,000[3]
8-b	P.H.S. laboratory	800,000	200,000[4]
	Total	$27,800,000	$2,725,000

[1] Loans to be repaid.

[2] To be distributed as follows: $850,000 to states, $60,000 to interstate agencies, and $90,000 for special studies of industrial wastes of regional or national significance.

[3] $75,000 of which was appropriated for fiscal year 1949.

[4] Fiscal 1949 appropriation to General Services Administration for plans.

Regulatory Features

The regulatory features apply to interstate waters only. The pertinent section of the Act states that pollution "which endangers the health and welfare of persons in a state other than that in which the discharge originates is hereby declared to be a public nuisance." In outlining the regulatory features of the Act, the action can be divided into a total of five major steps. These are, in outline, as follows:

1. The Surgeon General finds a "public nuisance."

2. The Surgeon General gives the first formal notice to the polluter. At the same time, he advises the state or interstate agency of his action and may outline remedial measures. Then he specifies a "reasonable time" for compliance.

3. The Surgeon General gives the second notice to the polluter, again advising the state or interstate agency. He may recommend that the state or interstate agency bring suit. If a second reasonable period passes with no abatement and the state or interstate agency fails to initiate suit to abate, then

4. The Federal Security Administrator may call a public hearing before a Board of five persons. This Board recommends reasonable and equitable

measures to abate the pollution and a reasonable opportunity is granted for polluter to comply.

5. With approval of the state water pollution control agency, the Federal Security Administrator may request the Attorney General to bring suit on behalf of the United States. The court "shall have jurisdiction to enter such judgment and orders enforcing such judgment as the public interest and the equities of the case may require."

Analysis of the enforcement clause indicates that several years might pass before effective Federal action could be taken. In this time there is ample opportunity to correct the pollution or to bring action under state authority. The provision requiring consent of the state before action is brought in the name of the United States means that the Federal government cannot interject itself into the affairs of the state in the matter of enforcement unless it has the concurrence of the state.

State, Interstate, Municipal, and Industrial Participation

With the thought in mind that particular interest has been shown in the impact on, and advantage to, the states and the municipalities and industries concerned, an effort has been made to summarize systematically the following items of participation or advantage.

State

The state retains its primary responsibility under the Act through its pollution control agency. Section 1 states that "it is declared to be the policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of the states in controlling water pollution." Specifically, the state enters the activity in the following respects:

1. It provides guidance and counsel to the Public Health Service and, specifically, to each river basin office in the development of the Federal program.

2. It cooperates in preparing comprehensive programs, or it may prepare a complete program, which the Surgeon General may adopt.

3. It is encouraged to engage in cooperative activities, enact uniform laws, and to negotiate interstate compacts.

4. It is subject to the regulatory provisions of the Act.

5. It furnishes representatives to act on hearing boards under the regulatory provisions.

6. It is required to give consent before Federal suit is brought.

7. It may request investigations, research, and surveys.

8. It may borrow money, properly secured (as may municipalities and interstate agencies), for treatment works construction.

9. Its approval is required for all loans.

10. It may be represented on the Water Pollution Control Advisory Board.

11. It may receive industrial waste study grants (states and interstate agencies only).

12. It may receive planning grants (as may municipalities and interstate agencies).

13. Its approval is required before planning grants are made.

Interstate Agency

In Section 1 of the Act it is "declared to be the policy of Congress to . . . provide Federal technical services to . . . interstate agencies and . . . financial aid to . . . interstate agencies . . . in the formulation and execution of their stream pollution abatement program." Specifically, an interstate agency enters the activity in the following respects:

1. It provides guidance and counsel to the Public Health Service and, specifically, to each river basin office in the

development of the Federal program.

2. It cooperates in preparing comprehensive programs.

3. It is encouraged to form compacts.

4. It may request investigations, research, and surveys.

5. It may borrow money, properly secured, for treatment works construction.

6. It may receive planning grants.

7. It may receive industrial waste study grants.

Municipality

In Section 1 of the Act it is "declared to be the policy of Congress . . . to provide Federal technical services . . . and financial aid . . . to municipalities in the formulation and execution of their stream pollution abatement programs." Specifically, the municipality enters the activity in the following respects:

1. It cooperates in preparing comprehensive programs.

2. It is subject to the regulatory provisions of the Act.

3. It may, through the state, request the Surgeon General to "conduct investigations and research and make surveys concerning any specific problem of water pollution confronting any . . . municipality. . . ."

4. It may borrow money, properly secured, for construction of treatment works.

5. It may be represented on the Water Pollution Control Advisory Board.

6. It may receive planning grants.

Industry

Section 1 of the Act says that it is "the policy of Congress . . . to support and aid technical research to devise and perfect methods of treatment of industrial wastes . . . (and) to provide Federal technical services . . . to industries." Specifically, industry enters the activity in the following respects:

1. It cooperates in preparing comprehensive programs.

2. For the purpose of carrying out the policy statement mentioned above, the Act provides that "the Surgeon General shall . . . support and aid technical research to devise and perfect methods of treatment of industrial wastes." However, the solution of industrial waste problems is the responsibility of the industries themselves.

3. It is subject to the regulatory provisions of the Act.

4. Through the state, an industry may request the Surgeon General to "conduct investigations and research and make surveys concerning any specific problem confronting any . . . industrial plant."

5. It may be represented on the Water Pollution Control Advisory Board.

6. The allotments made to states are for "the conduct of investigations, research, surveys, and studies related to the prevention and control of water pollution caused by industrial wastes."

Public Health Service Activities

Since passage of the Water Pollution Control Act, the President has appointed members of the Water Pollution Control Advisory Board (THIS JOURNAL, May, 1949, p. 552) and this Board has held an organization meeting (THIS JOURNAL, July, 1949, p. 718). [Subsequent meetings were held Oct. 3–4, 1949 and Jan. 10–11, 1950—Ed.] The Board gives promise of taking an active part in the program and making itself felt in the field of water pollution abatement.

A Division of Water Pollution Control has been created in the Public Health Service (THIS JOURNAL, May, 1949, p. 552). For the purpose of coordinating the Federal water pollution control activities with state and local programs, 14 river basin areas have been designated. Limitations in available funds made it necessary temporarily to combine certain areas, thus

reducing the number of river basin field offices from 14 to 10. These have now been staffed with river basin engineers and assisting personnel.

State water pollution agencies, established to receive state grants from a fund of $850,000, in accordance with Sec. 8 (a) of the Act, have been designated and allotments have been made (THIS JOURNAL, Sept., 1949, p. 850). Allotments also have been made from a fund of $60,000 to a number of interstate agencies, and from a fund of $90,000 to a number of states and interstate agencies for studies of industrial waste problems of regional or national significance.

A good start has been made on the comprehensive programs. Work sheets and final survey forms have been distributed. Progress is reported and several states have submitted completed data. There have been some objections to methods and timing, but few disagreements in principle.

The technical arm of the water pollution control activity is centered at the Environmental Health Center, Cincinnati, Ohio. Field activities which stress matters of regional or national interest have been devoted to bathing (THIS JOURNAL, January, 1949, p. 110) and irrigation water quality needs, pollution problems of international boundary waters (THIS JOURNAL, May, 1949, p. 525), basic industrial waste studies of the sugar beet and steel industries, and some miscellaneous projects. Field studies planned for the near future include industrial waste studies of sulfate or kraft pulp mills, in cooperation with the National Council for Stream Improvement, and studies of sewage treatment by preaeration and by recirculating filters.

Along the lines of basic research, the bacteriological laboratory has placed recent stress on indicator organisms and the effect on bacteria of ultrasonics. The biological laboratory is stressing toxicity studies and is making a detailed study of the biology of a small stream. The chemistry laboratory has projects which include important studies of analytical methods, the effect of heavy metals on biological oxidation, and the causitive agents of tastes and odors in water supplies. In view of the demand, research projects have been selected with great care.

Conclusion

Public Law 845 has provided authorization of appropriations for the period beginning July 1, 1948, and ending June 30, 1953. This is in the nature of a trial period of five years, after which it is presumably the intent of Congress to review the situation and determine if the program established should be extended and supported, or possibly should be revised. State, municipal, and industrial officials have, to date, been most cooperative with the Public Health Service and the General Services Administration. If the closely coordinated efforts experienced to date among cooperating parties are typical, we look forward with confidence to a successful program.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

LABORATORY TESTS FOR SMALL SEWAGE TREATMENT PLANTS *

Chairman LeRoy W. Van Kleeck, Sanitary Engineer, Connecticut State Health Department, Hartford Conn.:—The subject of what the laboratory tests for the small sewage treatment plant are and should be is controversial. Certainly there will be some differences of opinion. As a beginning, therefore, two well-qualified men have been selected to present their views before the matter is opened to general discussion.

Wallace W. Sanderson, Chemist, Division of Laboratories and Research, New York State Department of Health, Albany, N. Y.:—The value of any laboratory test depends on the method of sampling, and yet this is one procedure for which no definite directions can be specified for all plants. The purpose of the study, the tests to be made, the time and labor available, the location of sampling points, and many other factors must be considered.

Certain generalities can be emphasized. Samples should be collected where the sewage is well mixed; large particles should be excluded, and no accumulated deposits, growths, or floating matter should be included. If held for more than an hour before examined, samples should be cooled by immersion of the sample bottle in ice water.

Two types of samples may be collected—catch samples or integrated samples.

The ideal condition would be to analyze catch samples collected at hourly intervals during a 24-hr. period. This obviously cannot be done at small plants because time and staff are not available. Therefore, one catch sample at the time of maximum flow, which generally corresponds to maximum load, may be examined. Presumably, if the results indicate satisfactory operation at this time, satisfactory operation will be obtained at other times. When catch samples are used to determine the efficiency of treatment units, the effluent sample should be collected after a period corresponding to the flowing-through time so that the same sewage will be sampled at the inlet and outlet.

Integrated samples indicate the character of the sewage over a given period of time, the effect of intermittent changes in flow and concentration being eliminated. The portions used should be collected as frequently as feasible and should be proportional to the sewage flow. However, it must be understood that mixing of the individual portion can cause marked changes—neutralization of acid or alkaline portion can occur; coagulation and precipitation can change the suspended solids;

* From transcript, 1949 Operators' Forum, 22nd Annual Meeting, Federation of Sewage Works Assns.; Boston, Mass.; Oct. 17–20, 1949. [This was one of the six topics discussed; others will be presented in subsequent issues.—Ed.]

residual chlorine and pH values may be affected. Thus, the results are not typical of the sewage that passed through the plant at any instant.

If small sewage plants are considered to include primary sedimentation with sludge digestion and chlorination of the plant effluent, a very few simple laboratory tests can be of great aid in plant operation. The principal function of sedimentation is to remove settleable and floating solids. Therefore, a test that indicates the quantity of settleable solids in the influent and effluent of the tank is all that is necessary to show how much material is to be removed and with what efficiency it is being accomplished. The Imhoff cone test yields these data and requires little equipment and no special skill. If the results indicate that from 95 to 100 per cent of the settleable solids are being removed, the tank is accomplishing the purpose for which it was designed.

Sludge digestion is a process to convert the settled solids removed from sewage into an inoffensive compact residue that can be discarded without nuisance. It is a biologic process whereby the putrescible organic content is liquefied and gasified, leaving a humus-like material. A test to determine the quantity of dry solids in the sludge and the proportion of such solids that are volatile on ignition gives information regarding the quantity of solids to be digested and how well this is accomplished. A moderate amount of equipment is required and some skill in its use must be acquired. Generally, digestion will consolidate the solids from 2 to 5 per cent in the raw sludge to 5 to 10 per cent in the digested sludge, and reduce the volatile matter from 75 per cent of the dry solids in the raw sludge to 50 per cent of the dry solids in the digested sludge.

The digestion process proceeds most rapidly within a small range of pH values and can be stopped entirely by wide pH fluctuation. A simple, easily operated pH color comparator is available and is of great value to an operator in maintaining proper conditions for digestion. Generally, in the pH range from 6.8 to 7.4, digestion proceeds smoothly. Variations from these values can be detected and corrective measures applied before serious trouble develops.

Chlorination of sewage effluent is generally practiced to destroy pathogenic bacteria. The bacteriologic examination of sewage is long and tedious and entirely impractical at a small plant. Experience has shown that if sufficient chlorine is added to sewage effluent to maintain a residual of 0.5 p.p.m., 15 minutes after the chlorine has been applied, effective disinfection will be accomplished. The equipment required is but a small addition to that needed for pH determination and is as easily operated. If the chlorine added is enough to produce a 0.5 p.p.m. residual during maximum flow of sewage, it will be more than sufficient during the rest of the day, and the excess during low flows will amount to so little chlorine that it can be disregarded in small plants.

Thus, for small sewage plants, essential equipment can be purchased for about $300, which with simple laboratory procedures and careful sampling will make it possible to secure data of great value. The tests recommended are:

1. Determination of settleable solids.
2. Total and volatile sludge solids.
3. pH.
4. Residual chlorine.

None of these tests requires standard solutions or use of an analytical balance.

Frank Woodbury Jones, Consulting Engineer, Cleveland, Ohio:—In this discussion, the small sewage plant is regarded as one which has only a lone operator for routine duty. Obviously, as with most small plants serving say 5,000 or less persons, there will be no

attendant for at least two-thirds of the time.

Irrespective of its size, the sewage treatment plant, under present conditions of public and governmental insistence on and propaganda for clean waters, is an important cog in the maintenance of public health. The small plant should perform as continually and as effectively as its more pretentious counterpart. Basically, therefore, and in order to meet the requirements of the receiving waters, there is no difference in the elements of design or the necessity for proper and effective operation and control. Also, the factors by which the performance is judged by remote supervising agencies are essentially the same in all cases.

In the design of every sewage plant, large or small, provision should be made for some laboratory determinations. For the small plant, a single desk equipped with water, gas, and electricity, a sink, balances (analytical and heavy duty), together with other equipment such as graduates, beakers, burettes, bottles, evaporating dishes, chemicals, etc., will suffice for simple tests—or for show and preparing lunch if nothing more—at small expense.

It is at once apparent, however, that the small community can neither afford nor justify the employment of a full time operator, who is both a skilled chemist or engineer and an able-bodied laborer capable of performing all the duties of technical control and physical manipulations of routine plant operation, repair, and maintenance.

We do not hold to the statement, often made, that it requires a trained chemist to perform the simple analytical procedures required for most of the routine tests essential to an evaluation of plant performance. Experience has demonstrated that a skilled machinist who found himself operating a sewage plant could be as deft in using a delicate balance, pipette, or burette as he is in manipulating a micrometer—although he might not know whether B.O.L. meant biochemical oxygen demand or, as one applicant stated in a civil service examination, "bacterial, odor, decay."

As a first premise, therefore, an operator of good mechanical ability and fair intelligence can be taught to perform the mechanical manipulations of laboratory tests which do not involve the more complicated procedures, such as quantitative precipitations, and incineration. It is surprising, too, how soon he becomes dexterous and gathers some significance of the results obtained.

For the instruction and guidance of the non-technical operator, the community should employ a part-time technical supervisor who knows the art of sewage treatment and control. This is encouraged in some states, and with good results. The technical operator of a large plant can often make arrangements with his employers to permit him to supervise nearby small plants, by visits of as few as one to a maximum of not over four per month, except in unusual circumstances.

Observations of conditions and records of what devices are operated are just as important for effective operation as any technical determinations made in the laboratory. All of these office duties may be grouped under the general term "laboratory tests."

Using the broad interpretation, the following laboratory tests can be made with a minimum of time and effort. Just how many will be made depends on the interest and capacity of the operator.

Daily observations and recordings should be made of weather conditions; sewage flow; devices in operation; occurrence of odors; the time and duration of by-pass use; removals of screenings, grit, and sludge (wet and dry) and the quantities of each; as well as any out of ordinary happenings, such as foaming, occurrence of oil, and like disturbances. Most of these should be entered daily on prepared forms in

books for permanent record. A page-a-day diary is a necessity.

The conscientious operator likes to do some analytical work, which gives him not only a feeling of competence, but also one of confidence. At this point, it might be well to observe that the lone operator cannot spend too much time taking samples and preparing composites. Obviously, most of his efforts in this direction will have to be made during the day shift. A catch sample of raw sewage, taken, say, at 10 or 11 A.M., will in many instances, especially where there are no complications from intermittent dominant industrial wastes, give a fair indication of the average sewage. Another, taken of the effluent after allowing appropriate time for primary and secondary treatment, will permit evaluation of the treatment effected. Broader coverage can be secured by changing the sampling hours for raw sewage on different days (say at 8, 9, 10, 11, or Noon) with corresponding allowances for the steps in treatment. Also, it must be recognized that if the day effluent is acceptable, the night effluent ordinarily will be better.

The determination of settleable solids in raw sewage and effluents by the use of Imhoff cones is simple and gives a good indication as to whether primary and secondary sedimentation is effective.

For final effluents where complete treatment is used, methylene blue tests in spite of all objections by the savants, are valuable in depicting whether or not the end discharge is stable.

Again, for a complete treatment plant, methyl orange determinations of alkalinity will furnish valuable data on the effectiveness of treatment. A good final effluent from secondary devices will show a decided drop in alkalinity over that found in the raw or primary settled sewage. Where the alkalinity ranges from 150 to 400 p.p.m. in the primary settled sewage, a reduction of 30 per cent or more will usually indicate a well purified effluent equivalent to 85 per cent or greater removal of B.O.D.

Solids in sludge, both fresh and digested, should be determined regularly, and from composites made from frequent samples taken during the withdrawal. This is an elementary procedure and the securing of reliable results is fairly positive.

When chlorination is employed, tests for residual chlorine can be made without burden on time or effort.

The tests enumerated are regarded as minimum requirements if any laboratory bench testing is done at all.

The dissolved oxygen content in the receiving water above and below the point of effluent discharge is important, particularly on a small stream. There is no better indication of the sufficiency of oxygen and lack of toxic materials than the presence of minnows or other fish in the vicinity of the outlet. Where fish are present, no laboratory D.O. tests are necessary, but their living presence should be recorded, even if it is necessary to maintain in the effluent or stream trapped gold fish or other members of the finny family that depend on oxygen for survival. A number of plants keep fish in the secondary settling tanks. If the fish die, the conclusion is obvious.

Suspended solids can be determined by difference, (from residues on evaporation of both filtered and unfiltered samples) or direct (by Gooch crucible). Removals by settling tanks can be checked by determining the total solids in both influents and effluents. The necessity or reliability of these determinations on the small plant, in most cases, may be questionable.

B.O.D. determinations are not recommended as routine for the small plant operator.

Should it be desired to obtain overall results, weekly or monthly composites can be made by adding daily

samples (1 hr. per day), proportionate to flow, to a large bottle (say 1 gal.) in the presence of a suitable sterilizing agent depending on the determinations required. Old standbys in New England are formaldehyde for solids, and sulfuric acid where determinations of nitrogen as ammonia and nitrates and of oxygen consumed are made. The work on the composites should be done by the supervisor.

At present, the preparation of analytical reagents need be no deterrent. Every chemical house can supply standard solutions of any strength desired, either in full volume or in capsules to be made up in the laboratory. Here, however, the work of preparation preferably should be done by a qualified chemist.

In the experience of the writer, it is difficult to maintain a schedule of routine testing on the small plant. Consequently, reliance must be placed on the faithful performance of routine duties which will effect maximum performance of the treatment devices. Where possible, however, the making of simple determinations as above outlined, though not essential, is desirable and will enhance the standing of the operator in the eyes of his fellow operators, the community, and governmental supervisors.

The worth of a sewage plant depends on how well it accomplishes its intended purpose. Success or failure in attaining the desired end can be evaluated from technical tests and from plain common sense observations. Both are desirable; but if only one is possible, let it be a faithful record of conditions observed in the several phases of treatment and in the receiving waters. A black, smelly stream below a sewage plant outlet needs no other confirmation of failure in treatment. Conversely, a reasonably clear and clean effluent and a stream supporting fish life above and below the point of discharge needs no B.O.D. or other chemical test to prove the acceptability of plant performance.

T. C. Schaetzle, Superintendent, Sewage Treatment Plant, Akron, Ohio:—I would like to inquire as to whether there is any uniformity among the health departments as to the sampling that is done at a small plant. Mr. Sanderson remarked that the sampling was highly essential. We all agree with that. I have wondered if, rather than taking one sample a day, it would not tell more about the operation of a small plant if a composite were taken, say, once a month. By the law of averages, such samples might indicate a little better what the plants are doing. Or, if possible, perhaps a sample taken four or five times a day each week, but on various days of the week would be better.

Chairman Van Kleeck:—Are you referring to the sampling of raw sewage at the plant influent?

Mr. Schaetzle:—That is right; and for small plants.

H. L. Giles, Sanitary Engineer, Connecticut State Health Department, Hartford, Conn.:—The Connecticut State Health Department makes an effort to have one of its inspectors sample every treatment plant of any consequence every three to four months. A few factories and small plants are missed. Sometimes a sampling is obtained a little more frequently or a little less frequently, depending on conditions. A composite sample is taken over a period of 5 or 6 hr. at 10- or 15-min. intervals; that is, while the man is there he does nothing else but that. In addition, in the very small plants, we have tried to get the men to take a sample at different hours, as Mr. Sanderson has pointed out, so that over a period of a month we have not only residual chlorine tests, but also, in the case of a secondary treatment plant, acid solids tests and stability tests at different times of the day. By so doing a pretty complete picture

of what is happening at the plant can be obtained from a review of one month's records.

R. M. Babcock, Sanitary Engineer, Nebraska State Health Department, Lincoln, Nebr.:—In answer to the question, we have attempted to visit each plant, although the frequency of the visits has been curtailed by lack of personnel. During each visit we make a 24-hr. composite sampling at 30-min. intervals and run complete tests. That is done by State personnel almost entirely, with the help of the operator, of course, or such other help as is available. We feel that in this way we can determine at least what the condition of the plant is, the operation, and, of course, the final effluent. We'd prefer to do it every 2 or 3 months, as was suggested; but we just can't. However, we do feel that the effort is well worth-while.

Mr. Sanderson:—Apparently, my point has been misinterpreted. The state health department sends out a representative to take samples and try to get a picture of the plant operation. I was referring, however, to the plant where the operator does some of the simpler tests. He is busy with all kinds of duties and just takes one sample a day.

Now, would it be better, in the opinion of the various health departments, if those men who are doing their own sampling and making their own simple analyses did not take a sample every day, but instead set aside one day of each week to be a sampling and analysis day, during which samples would be taken several times and the analyses made immediately, perhaps rotating the day during succeeding weeks?

G. F. Bernauer, Sanitary Engineer, Wisconsin State Board of Health, Madison, Wis.:—We at Wisconsin haven't had the opportunity, because of personnel problems, to make detailed checks on the sewage plants from the state level. However, we have advocated that the smaller sewage plant operators do exactly as Mr. Schaetzle suggested. Many of these small plant operators have taken samples at ½-hr. or 1-hr. intervals over a period of, say, an 8-hr. operating day, and staggered the day of the week on which the samples are collected. In that way, we feel that we get a pretty good picture of what is going on in a lot of these small sewage plants.

M. M. Cohn, Sanitary Engineer, Schenectady, N. Y.:—In closing his discussion Mr. Jones made a very fine point when he said that, "With all of the laboratory determinations, the eye of the operator will tell him at his diluting stream whether he is or is not doing a reasonably good job."

As an operator of rather long standing, I have been pleading for proficiency in sewage treatment plant operation to meet the requirements of the state health department—these men who have arisen in the defense of their own standards of practice. However, from my experience during the last 3½ years of going out to seal stream plugs, we must begin to measure efficiency of plant operation, not only by B.O.D., but also by what I'd like to call P.O.D., which stands for "Public Observation Demand." Besides producing good effluents streams must be made to look good if we are to get the money required to build the needed sewage plants.

It is a good point: all operators ought to be taught to spend a little time down at the outlet stream to see whether or not they are really performing the job they could.

C. C. Larson, Chemist, Springfield (Ill.) Sanitary District:—I believe Mr. Jones will have a little difficulty in defending his position relative to the correlation of alkalinity and B.O.D.

Mr. Jones:—I got that through observation, not through any deductions. Nevertheless before I wrote that I went over several years' records of various plants and the statement held good every time.

REGULATION AND CONTROL OF INDUSTRIAL WASTES DISCHARGED TO SANITARY SEWERS *

By G. R. Scott

Sanitary Engineer, Black and Veatch, Consulting Engineers, Kansas City, Mo.

Inasmuch as the technical journals contain a vast fund of information on the effect of industrial wastes on sewers and the operation of sewage treatment plants, it would seem a simple matter to summarize these data and conclude with an outline of an ordinance or regulation that would constitute a method by which a satisfactory solution of this aggravating problem could be achieved. Apparently, however, this idea is erroneous. There have been discussions of that type, yet the problem is still unsolved. Excellent summaries have been prepared in which tolerance limits for various substances are indicated, and the technical journals contain detailed information on almost every type of waste. In general, the technical information required for the solution is available, but this is not all that is required for a satisfactory solution. Something is lacking which is necessary to organize the program and make it click.

The Federation's Committee of Sewage Works Practice has prepared Manual of Practice No. 3 on "Municipal Sewer Ordinances" to serve, as stated in its preface, as " . . . a guide to assist municipalities in the proper regulation and control of sewage works. . . ." Much good can be expected to ensue if this work is accepted and followed. However, a regulation without popular support cannot be entirely successful. So, in a searching manner, the suggestion is offered that perhaps, in addition to emphasizing the regulation and control of wastes, some time should be devoted also to study of the human relationships involved in the program.

Some of the problems of waste regulation might disappear if the considerations and tolerances with which we are concerned in normal living activities were applied also to dealings with wastes and their originators. Perhaps, eventually, it can be demonstrated that the subordination of individual interests with respect to sewages and industrial wastes is conducive to the well-being of a community, and maybe even to that of the entire area of a water shed.

Our first concern is with the administrative forces. It is on this group that most sewage superintendents must concentrate their efforts, because reaction to any program outlined will depend on comprehension of the problem and the importance of its solution. The essential service provided by a sewer system to a community in promoting public health and in affording a convenient method of carrying away its waste products should be considered equal in importance to other utilities and should be treated as such. Like other utilities, it should be operated as an entity in itself, with charges for its services in proportion to the use. In many cases, it is only by such means that a municipality will be able to finance adequate sewage works.

It is not the intent here to discuss the elements to be considered in establishing the amount to be charged for the services. They have been described in the Tentative Manual of Practice, entitled "Uniform System of Accounts for Sewer Utilities," pub-

* Presented at 1949 Annual Meeting, Kentucky-Tennessee Industrial Wastes and Sewage Works Association; Lexington, Kentucky; Oct. 31—Nov. 2, 1949.

lished by the Federation. Briefly, they include costs due to capacity (amount of sewage), to the commodity (power and supplies of various kinds), to users (meter reading, billing, collecting), chargeable to public (service to public property), and resulting from unusual conditions (difficulty in providing service, or wastes of such characteristics as to result in extra treatment costs). When charges based on these elements have been worked out and properly applied to wastes and sewages, many of the problems of regulation and control will be solved. When an industry is faced with charges for excessive amounts of waste or for particular processes in treatment because of abnormal strength or peculiar characteristics, it is conceivable that it will attempt to minimize such requirements by examining its own household. This may result in modification of process, recirculation and re-use of water, recovery of materials, primary treatment, or any other step which the industry can undertake to its advantage to decrease the cost of treatment at the municipal plant.

Utility Status of Sewer Service

On the other hand, sewer services should be considered as a utility on a par with water supplies or electrical energy by civic groups and the administration in their efforts to locate new industries in the community. Ordinarily it is assumed as a matter of course that if the water requirements or the electrical load required by an interested industry will exceed existing facilities, mains, power lines, and even plant enlargements will be installed to meet the requirements. And why not? Community progress depends on industrial development. Also, the new enterprise is a potential consumer of a revenue-producing utility. Is it illogical to presume that, with respect to the disposal of wastes from its activities, this industry should at least pay its own way? This is a point for sewage superintendents to emphasize in discussions with their employers and the general public. They are not asking for the adoption of charges which are in excess of the cost of providing the service. Nevertheless, there should be received an amount, equitably imposed, which will enable operation and maintenance of the system in a good working condition.

Make Public Sewage Conscious

A little advertising and the distribution of information on what the plant is and what it can do will not hurt the program. Get the Mayor and the City Council to go over the sewer system and see for themselves some of the difficult problems—and then be sure that they become familiar with the sewage treatment plant. Get the industrial fellows down to the plant and show them how it works and why some wastes are detrimental. The general public should also be enticed to the plant and made sewage conscious. Of course a well-kept plant free of weeds and unsightly debris, along with a few flowers, will help give the plant more public appeal.

If the sewer system has been placed on a utility basis, it is assumed that the industrial wastes are being measured by some recording and integrating device and that enough analytical work has been done to provide information on their characteristics. Otherwise, how can it be possible to establish a fair charge for their treatment and disposal? Also, by the time this charge has been worked out, it is quite certain that unnecessary fluctuations in flow and strength have been smoothed out so that the upsetting effects on the treatment plant of sudden surges of flow and abnormal organic loads will be minimized. The industry has examined its operations. It has sepa-

rated the clean condenser water from the waste, and by modifications and better housekeeping has found that it can keep the amount of waste and the organic matter to a surprisingly low amount. It is assumed, too, that the city has done its part in providing adequate capacities for the load to be carried, and all that is left for the sewage superintendent is the relatively easy job of seeing that it operates.

But is it easy? Because of faulty operation or mistakes at the industrial plant, or because of spills or a break in some pipe line, sudden loads reach the sewage plant and the sewage may be colored all shades of the rainbow, or contain so much organic material that the treatment processes are upset. Eventually, of course, the stuff passes to the receiving stream. Its effect on the plant may be felt only momentarily or, depending on its nature and the type of treatment plant, it may reduce the plant efficiency for as long as a week or more.

Cooperation of Industry

Although it is unreasonable to require that such occurrences be prevented entirely, it does appear to be within reason to expect cooperation on the part of industry when such abnormal wastes are discharged to the sewers. This cooperation could in general be evidenced first by a telephone warning to the sewage superintendent, giving him the approximate amount and general characteristics of the wastes. With this information, and a few minutes grace, he can prepare either to receive them or open the by-pass gate. The second action of cooperation should be the immediate repair of the break, and perhaps the installation of equipment required to minimize the possibility of a recurrence of such accidents.

In order to obtain this cooperation, it is essential that the sewage superintendent be well acquainted with the personnel responsible for the maintenance and operation of the waste systems at the industrial plants. He should be familiar with the processes and the individual wastes to the extent that he can appreciate the problems of the industry as well as estimate the effects of the wastes on the operation of his plant.

Municipal Responsibility

It is generally believed that progress in stream sanitation depends on the treatment, whenever possible, of industrial wastes along with domestic sewage. Accordingly, municipalities should recognize this requirement and where practicable and economical should make provisions to receive the industrial waste for treatment. However, even with the restrictions which have been outlined, there are certain wastes which will damage or clog the sewer system and which are not amenable to the treatment usually provided by the municipal plants. The discharge of such wastes to the sewer system should not be permitted until they have been so treated by the industry that they can be received without danger. It is at this point that we might begin to consider the regulation and control of wastes.

Article V of the Federation's ordinance is prepared to prevent or limit the following:

1. Damage to the sewer system by explosions, acids, or clogging by inert solids or greases.
2. Public health hazards.
3. The discharge of toxic wastes or those not amenable to usual plant treatment processes.
4. Wide fluctuations in amounts of sewage.
5. Abnormally strong sewage, or those with such widely varying characteristics as to be objectionable.

It is believed that a program such as has been outlined will automatically re-

move the need for much further consideration of the last two conditions. The need still remains, however, for regulations to obtain the required control over the first three conditions, but if the sewer rental law is not in effect, all five must receive adequate attention.

The preparation of Article V for a particular municipality should be undertaken only after a complete study has been made of the problems involved, and the limits to be included should be practicable and no more rigid than will be necessary to protect the system and its operation. Industry should be asked to participate in the studies and in preparation of the regulations. They are users of the service and must assume their proportional share of the construction, operation, and maintenance costs. They are generally quite familiar with the characteristics of their own wastes but usually do not appreciate the effect of such wastes upon the system. The Federation's Committee in its discussion of the preparation of the ordinance failed to include industry in their suggested list of personnel for an ordinance committee. Industry should be represented, along with the municipal officials and their technical advisors. This democratic approach should result in a better understanding by all and a document mutually agreed upon, which will be more easily administered than one developed without due consideration of all interests. Such a method has been followed and Detroit reports excellent results in the operation of its regulation, prepared in such a manner.

The Committee used good judgment in stating that the limiting value for the organic load should be left to the judgment of the superintendent of sewage treatment or to the city's consulting engineer. This should also be the case for fluctuations in the amount of flow. The ordinance is adequate with reference to limiting conditions which will damage or clog the sewer system, and the public health hazards have been considered. Toxic or poisonous substances are limited in the ordinance to concentrations below those which might "injure or interfere with any sewage treatment process, constitute a hazard to humans, or animals, or create any hazard in the receiving waters. . . ." It is realized that present knowledge on acceptable concentrations of toxic substances is limited, but it is regrettable that the discussion of this subject did not summarize the concentrations of those materials which have caused trouble at sewage treatment plants. This would have made the discussion on toxic substances of equal value with the sections on B.O.D., solids, pH, etc., to those preparing an ordinance.

Outside Help May Be Needed

In this discussion, emphasis has been placed on the duties of the sewage superintendent. Obviously, it is out of reason to expect the facilities and skills required for the detailed analyses of the wastes to be available in the smaller municipalities. The treatment of wastes is an important portion of the stream sanitation program now being developed by the states. Their personnel should be called on for assistance. In many cases, outside help must be obtained.

Perhaps by the combined efforts of all groups which fundamentally are interested in this important service, and by a democratic approach, a sewage works system can become more than a conduit with a plant on the lower end into which wastes are dumped in a hurry and without due consideration to the well-being of the communities. It is not proposed to raise sewage to a higher plane—it should remain underground—but sewer service should be raised out of the ditch so that it can be seen in its true light and appreciated equally as much as any other municipal service.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"Start where you are with what you have; make something of it; never be satisfied."—*Carver*

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.

Eleventh Annual Report of the Racine, Wis., Sewage Disposal Plant and System for 1948 *

By Thomas T. Hay, *Superintendent*

Although the average daily flow was 14.565 m.g.d., or 11 per cent less than that for 1947, it was still 21 per cent over the designed capacity of the plant. Probably the decline was due primarily to the shortage of rainfall, there being recorded only 21.60 in. of precipitation at the plant, or about 2/3 of normal.

In contradiction to the decreased flow, both the total amount of dry solids delivered to the plant and the total amount removed were slightly higher than in 1947. Despite the obvious overloading of the plant, efficiencies continued to be average or above for similar plants.

Digester loading is 81 per cent greater than the average for a number of plants, being greater than the maximum at which complete digestion may be expected under optimum conditions. No excess capacity is available to meet daily, weekly, or seasonal maximums or any shock load that may be put on the digesters. Although dry solids drained to the beds (749,480 lb.) constituted 11 per cent more than was handled by the beds in 1947, it was still necessary to chlorinate and waste a large amount due to inadequate capacity of the beds.

Maintenance and Repairs

In addition to normal inspection and maintenance schedules, painting schedules were set up to utilize all available labor. Installation of a new insulated roof deck and roofing reduced moisture in the plant sufficiently to make such a procedure possible. The old pre-cast concrete tile flat roof had deteriorated so badly, because of moisture and temperature attack, that many of the tiles were held by up the roofing, making it dangerous to work under that area. The new deck is composed of 2-in. D and M lumber treated with chromated zinc chloride. On this was laid 2 in. of fibre glass insulation, which was covered with a 20-year bonded roofing. The contract for the work was $39,996. It is intended to add sufficient heating and circulating units to dry the atmosphere beneath this roof, thus prolonging the life of the entire structure.

Unusual Operating Conditions

Rags collecting on the clarifier chains had been causing them to jump the sprockets, being shredded to strings in the process. To correct this, a 2-in. bar screen was shop made and placed in the influent channel ahead of the comminutors. This was used only during the spring months when the sewers were flushed out by high flows. No clarifiers have been out of service since because of breakdown.

A heavy discharge of gas plant wastes during 1947 continued to affect two of the digesters until well into Feb-

* For last previous extract see This Journal, 21, 1, 120 (Jan., 1948).

ruary, and the third until the end of May.

Table I is a summary of the 1948 operating data.

TABLE I.—Summary of 1948 Operation Data at the Racine, Wis., Sewage Treatment Plant

Item	Average
Total rainfall (in.)	21.60
Sewage flow (m.g.d.)	14.56
Per cap. sewage flow (gal.)	187
Settling tank retention (hr.)	2.4
Settleable solids:	
Influent (ml. per liter)	3.69
Effluent (ml. per liter)	0.20
Per cent reduction	95
pH:	
Influent	7.7
Effluent	7.7
Suspended solids:	
Influent (p.p.m.)	179
Effluent (p.p.m.)	83
Per cent reduction	54
B.O.D., 5-day:	
Influent (p.p.m.)	121
Effluent (p.p.m.)	73
Per cent reduction	40
Chlorine demand:	
Raw (p.p.m.)	5.65
Effluent (p.p.m.)	5.74
Raw sludge to digesters:	
Gal. per day	20,421
Per cent dry solids	8.05
Pounds dry solids	12,114
Per cent volatile solids	63
pH	6.7
Digested sludge:	
Pounds digested solids to drying beds	2,048
Per cent solids	12.71
Per cent volatile solids	42
pH	7.06
Per cent solids in supernatant	1.03
Analysis of dry sludge (%):	
NH_3	2.66
P_2O_5	2.07
K_2O	0.47
Grease	3.61
Humus	43.0
Moisture	33.0
Gas, cu. ft. per capita per day	0.57
Gas analysis:	
B.t.u.	654
Oxygen (per cent)	1
Nitrogen (per cent)	2
Hydrogen (per cent)	2
CO_2 (per cent)	31
CH_4 (per cent)	64
Operating costs ($):	
Per capita	0.92
Per m.g.	13.51

Annual Report of the Sewage Works Manager, Borough of Slough, England, for the Year 1948–49 *

By M. A. Kershaw, *Manager*

Treatment

Although the total volume of sewage handled during 1948–49 was slightly less than during 1947–48, the overload on new sections of the three treatment plants (Cippenham, Dorney, and Langley) was increased owing to partial collapse of the old works. During peak flow periods of the year (3,757 hr.) a considerable volume of sewage was bypassed into the storm-water tanks for storage until periods of slack flow, when it was returned through the plants for treatment.

The strength of the sewage was again considerably above average, due primarily to industrial wastes. Routine analyses indicate the average sewage strength to be approximately 25 per cent higher than the previous year. Average purification of 85.93 per cent was effected, as compared with 87.4 the year before.

Collapse of the dosing chamber at the old works put this unit out of service for several weeks until temporary repairs enabled 3 of the 5 filters to be brought back into limited use. As a preliminary to plant additions, 5 of the irrigation lagoons were taken out

* For last previous extract see This Journal, **20**, 6, 1106 (Nov., 1948).

TABLE II.—Analyses of Trade Wastes, April 1948–March 1949*

Type	No. of Samples	pH	Oxy. Absorbed N/80 $KMnO_4$ Lab. Temp.		Chlorions	Nitrogen				Acidity or Alkalinity as $CaCO_3$	Suspended Solids	B.O.D. 5 Days at 18.3° C.	Remarks
						Ammoniacal		Oxidized					
			(3 min.)	(4 hr.)		NH_3	NH_2	NO_3	NO_2				
Acid Wastes	30	5.9	9.4	33.5	147	0.8	0.9	0.17	1.7	653	224	51	Cr·Fe·HF·Cu
Plating Waste	44	5.4	2.7	11.8	143	7.7	3.9	1.12	18.2	44	219	2	Cyanides, Ni, Zn
Lead Paint	29	6.9	177	209.3	451	3.3	0.5	0.8	94.6	5,402	340	422	Total lead as PbO-4577
Syn's., Chemicals	35	7.8	185.3	613.3	492	26.1	8.0	0.06	Nil	2,782	431	1,643	Solvents, Paints, Oils, Cr.
Fats, Soaps, Cosmetics	26	7.8	18.8	51.1	317	18.9	2.3	Nil	Nil	319	379	2,670	Solvents, Soaps, Grease
Foods and Confections	39	6.7	43.5	1,900	176	6.7	6.8	Nil	Nil	289	407	3,802	Sugars, Starches, etc.
Gas Liquor	10	8.0	6,890	10,554	5,049	6,061	222	—	—	2,420	144	—	Sulfides, CNS, Phenols, etc.
Starch and Glue Products	4	7.3	58.0	310.8	138	0.3	1.7	Nil	Nil	344	496	2,060	Free Starch
Wallpaper Manufacture	9	6.8	5.8	52.9	101	0.7	1.6	Nil	Nil	258	1,877	325	Cu, Zn, Ni, Cr, Starch
Rubber and Latex	11	7.2	104.7	323.6	97	485.3	13.2	Nil	Nil	927	1,033	443	Coag. Rubber
Dyeing, Bleaching Textiles	9	6.1	35.0	136.4	532	3.4	2.9	Nil	Nil	18	57	148	Free Chlorine, Sulfides
Anodizing	3	6.9	0.4	3.9	96	0.4	0.3	0.03	Nil	200	Nil	7	
Surface Waters	26	7.9	7.1	20.2	111	6.2	3.6	Nil	Nil	397	2,440	96	Fats, Oils, Bitumen, Chemicals
Others	17	—	—	—	—	—	—	—	—	—	—	—	Seaweed, Sludges, etc.

* Results expressed in p.p.m.

of commission, creating still a further slight reduction in the treatment capacity of the works. In anticipation of further temporary interference with the existing plant during the construction program, work on farm irrigation areas is being intensified with a view to dealing with increased volumes of sewage liquor on the land at these times.

Langley

Deterioration of the final effluent of this plant (73.22 per cent purification as against 77.2 per cent in 1947–48) necessitated construction of a new filter, settling tank, and pumping station, as well as changes in land irrigation practices. The effect of the new units is seen in later purification figures averaging 84.2 per cent.

Laboratory

In addition to routine work and special attention directed towards obtaining information to assist in operating the new works when constructed, the laboratory did a considerable amount of work on experiments for the Water Pollution Research Board in connection with filter fly control and toxicity to fish of effluent from filters treated for fly control. In addition, long term research on the method of B.O.D. determinations was concluded and investigation was carried on of possible methods of pretreating a particularly strong industrial waste anticipated from a new local factory.

Trade Waste Effluents

During the year 1,021 inspection visits were made to factories and 292 samples of industrial discharges were obtained for laboratory examination. A total of 142 factories is now subject to regular inspection, with 32 new ones added this year. The volume of industrial wastes reaching the works is estimated at 450,000 g.p.d. (Imp.). Pretreatment units have been installed at 65 factories to balance both volume and strength of the discharges to the system. Table II indicates the wide variety both of trade wastes and their compositions and strengths.

Manor Farm

The primary object of the farm is as a unit of sewage disposal. During the year some 67 m.g. (Imp.) of sewage and most of the sludge was disposed of in this way, without nuisance. Some 5 acres were reclaimed by clearing the accumulated surface mat of rubbish and sludge, deep ploughing, and putting the area into irrigation use. The

TABLE III.—Summary of 1948 Operating Data, Cippenham Sewage Plant, Slough, England

Item	Average
Area of Borough (acres)	6,276
Population (estimated)	66,030
Rainfall (in.)	22.52
Average sewage flow (m.g.d. Imp.)	1.79
Per cent overload on treatment works	19.4
Total number samples examined	1,174
Individual estimates	9,036
pH:	
Raw	7.4
Settled	7.2
Humus tank effluent	7.1
Lagoon effluent	7.4
Oxygen absorbed (4 hr. N/80 $KMnO_4$, Lab. Temp.) (p.p.m.):	
Raw	172.0
Settled	112.0
Humus tank effluent	24.2
Lagoon effluent	38.3
Nitrogen (NH_3) (p.p.m.):	
Raw	77.7
Settled	72.2
Humus tank effluent	25.7
Lagoon effluent	41.1
Nitrogen (NO_3) (p.p.m.):	
Humus tank effluent	21.2
Lagoon effluent	0.2
Suspended solids (p.p.m.):	
Raw	670
Settled	177
Humus tank effluent	51
Lagoon effluent	50
B.O.D. (5 days at 18.3° C.) (p.p.m.):	
Raw	780
Settled	494
Humus tank effluent	34.7
Lagoon effluent	57

remaining 15 acres were dried off and the deposited sludge is now being sold and removed from the site.

A grass drying plant was put into operation in May, 1948, with a ready market for the high quality hay produced. A net profit of £258 was realized on 9 feeder steers sold, and an additional £176 on sludge sales.

A summary of operation data for the Cippenham works for the year April 1948-March 1949 is given in Table III.

SAFETY IN SEWAGE PLANTS*

By Gilbert H. Dunstan

Associate Professor of Sanitary Engineering, University of Alabama, Tuscaloosa, Ala.

Safety is all too often neglected, with the result that death and injury often result when a little extra effort could have prevented the causative accident. It behooves each man to be careful, lest he one day become an accident statistic.

There are three major factors which have a definite bearing on the problem of safety. First, there is the man himself—his knowledge or lack of it, his carelessness, and his attitude. Then there is the matter of having adequate and proper equipment and plant. Finally, there is the matter of maintenance. Without attention to all three, a safety program is bound to fail.

Personal Element

In some ways the personal element is the key to the whole matter. Unless a man becomes interested in safety, and then learns the fundamentals, the best plant in the world may not prevent injuries to him. Usually there is a right way and a wrong way to do every job —the right way is the safe way. The experienced operator probably knows this way, and he likely knows why; but the new man probably does not. Hence, as a basic principle, whenever a new man comes on the job be sure he knows the right way—the safe way—to do every job he must do. Just because he says he knows how should not keep his superior from observing and checking to be sure that he does. Make it clear to him that you are trying to operate a safe plant; that you know that accidents don't just happen, they are caused; and that you expect him to do his part in preventing them.

As the superior, never neglect to check up on any dangerous conditions reported by your men. Let them know you are interested, and if you find they are wrong, carefully explain why. If you are the subordinate, don't hesitate to report unsafe conditions—but don't criticize the boss too much if his board refuses to spend the money to do the job required. Do the best you can. Be a little more careful; don't take chances.

When safety devices are provided, use them. They may save you from injury when least expected. If you are tired, be doubly careful. Fatigue can be a killer—you may do the thing you know you shouldn't, and the price you pay for this slip may be painful and costly.

Equipment and Layout

In an old plant, equipment and plant layout may be far from satisfactory, and there may not be too much that can be done about it except to be extremely careful. Most modern machinery can be safeguarded so that it is extremely difficult to be hurt by it. It

* Presented at Fourth Annual Meeting, Alabama Water and Sewage Association; Tuscaloosa, Ala.; June 9–11, 1949.

is usually much better to buy a machine with built-in safeguards than to add them later; if they are added as an afterthought it is usually not too much trouble for an operator to remove them.

If you have any voice in the matter, insist that safety considerations be considered by the designer of any new plant or addition. It may not cost a penny extra to make a plant safe if designed that way; but correcting defects is likely to run into money, and so may not get done.

It is not possible here to go into great detail or to touch on every point, but an attempt will be made to mention a number of important points in design.

There are many danger spots around plants at which fencing, chaining, railings, and guards are needed to safeguard operators from physical injuries. This applies around manholes frequently left open, open settling tanks, stair wells, and any deep opening. As fencings and railings may hinder operation or increase the hazard under certain conditions, good judgment based on operating experience is needed by the designer or inspector when providing or recommending such safeguards.

Guarded machinery, properly insulated and grounded electrical wiring and equipment, non-slip stair treads, non-slip floors, adequate lighting, and provision of facilities for handling and caring for chemical spills are all basic requirements in design. Also in this same category are adequate fire extinguishers, proper signs, and judicious painting to reflect light and distinguish unsafe spots.

Around deep tanks a life preserver and throw-line may prove its worth. Even more important, however, is scheduling of the work around such tanks so that there is someone near to use the preserver if it is required.

First-aid equipment holds major injuries to a point of minimum severity and prevents infection from developing in the case of many unavoidable minor injuries. Treatment of all injuries, no matter how small, should be mandatory. Except for minor injuries, wounds should be treated by a doctor.

Rubber gloves should be worn to prevent infection while cleaning clogged sludge pumps, handling screenings, sewage, grit, and filth. This protection becomes doubly important when the hands are chapped or the skin broken.

Safety considerations with respect to combustible or poisonous gases are well covered in the literature, particularly in the Federation's Manual of Practice No. 1, "Occupational Hazards in the Operation of Sewage Works." The re-reading of this manual at frequent intervals should be a mandatory requirement of every person connected with a treatment plant or sewerage system.

Maintenance

The final factor is a matter of maintenance and good housekeeping. Equipment will get dirty, will wear out, or will otherwise become less efficient. A regular schedule of checking all equipment should be followed, and this checking should include all safety factors involved and all safety equipment. A discharged fire extinguisher is worse than no extinguisher at all. A first-aid kit with certain supplies exhausted may create a hazard.

Aisles and walkways should be kept clear, and free from grease. Worn stair treads should be replaced. Tools and equipment should have a specific place and should be kept there. Finally, it should be mentioned that cleanliness is a big factor in keeping down skin infections.

It has not been possible in this discussion to be specific on most points. Detailed safety data may be obtained for almost any type of situation from the National Safety Council and from U. S. Government publications. Manufacturers often provide useful data.

The Manual of Practice No. 1, previously mentioned, is specific in its application of good safety principles to sewage works practice. However, all the knowledge and the best equipment in the world cannot take the place of a real interest in safety on the part of each person involved.

EFFECT OF ACID IRON WASTES ON THE WORCESTER TRICKLING FILTERS

By Roy S. Lanphear

Formerly Supervising Chemist, Dept. of Public Works, Worcester, Mass.

Although it has been claimed that the trickling filters of the Worcester, Mass., sewage treatment plant were clogged with iron deposit as a result of iron and acid wastes in the sewage, several tests on the filters themselves indicate that such was not the case. Actually, the clogging of the 14-acre filter surface began as a bacterial growth, which reached such proportions that ponding resulted and fine sludge ultimately covered the filters and penetrated the top few inches of stone.

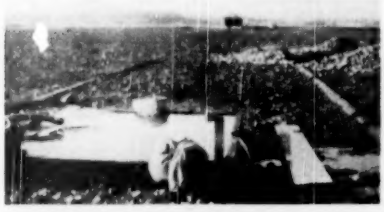


FIGURE 1.—Bottomless box on Worcester filters shows effect of bacterial and fine sludge clogging in surface layer.

In one experiment, shallow depths of stone were removed from several small areas of the filters. The cleaned areas were then dosed with Imhoff tank effluent, using 1½-in hose connected to nozzle openings on an adjacent operating filter. Each of the test areas cared for far more influent than the usual doses through the nozzle; that is, 8 to 15 sq. ft. of filter area successfully cared for more influent than usually was dosed to 168 sq. ft.

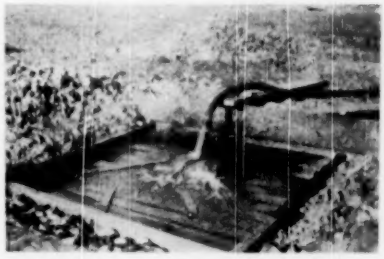


FIGURE 2.—With clogged top stone layer removed filters passed influent freely.

There was no pooling in any of the areas during a long series of tests.

In another independent experiment, a 5-ft. square bottomless box was set on the uncleaned surface of the filter. The influent did not pass down into the filter, but filled the box and continued to pass from it through an overflow opening at one side (Figure 1). A similar box set into the filter

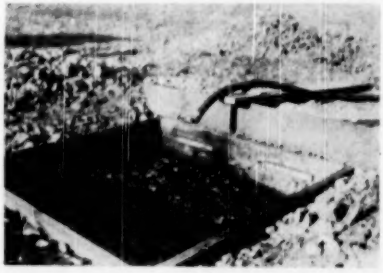


FIGURE 3.—Removal of clogged surface layer greatly improved filter performance.

after a few inches of stone had been removed from the surface (Figure 2) did not overflow, the influent draining freely to the filter below. In Figure 3 this same box is shown immediately after the experimental dosing flow had been stopped and the distribution platform removed. No ponding was evident. Figures 1 and 3 indicate that the clogging of the filters was entirely a surface condition and involved only the top few inches of stone.

A third experiment was carried out by still another independent source. In this test, 8 rows of stone (about 1 acre of filter area) were removed from between lateral pipe distributors on the filters to a depth of about 18 in. The remaining 6 acres of the test filters were left uncleaned. The entire 7 acres were dosed for 54 successive days at a rate of 2.25 to 2.50 m.g.a.d. The influent dosed on the one cleaned acre disappeared without ponding. However, the influent to the 6 uncleaned acres was not prevented from flowing and carrying solids with it into the adjacent cleaned ditches (400 ft. long). Subsequently, all 8 ditches became clogged in turn with the solids from the top of the 6 uncleaned acres. This corroborated the previous findings that the filters were not clogged throughout.

The rate of influent dosage on the ponding filters prior to the first tests was less than 1 m.g.a.d.; the normal average rate was 1.5 m.g.a.d. In the third test it was estimated that the cleaned acre received from 12 to 15 m.g.a.d., or 8 to 10 times the normal dosage rate. All test results indicated that the Worcester trickling filters were not clogged with iron deposit.

TIPS AND QUIPS

Really Non-Clog Pump

A truly revolutionary development in sewage pumping equipment recently came to light with a public demonstration of the new Fairbanks-Morse bladeless trash pump. Intended for pumping sewage and other liquids containing large pieces of fibrous trash, the unique pump uses a single channel without blades, the pumping effect being obtained by the use of a warped and twisted channel (Figure 1) equivalent to one flow section of a conventional impeller. With a completely obstruction-free impeller passage and no blades, there is no place where trash can become lodged or wedged in its passage through the pump.

Claims that the new pump will handle trash 10 times the size that will clog any pump with blades (and on occasion trash up to 25 times as large as can be passed by conventional pumps) were visibly substantiated at the recent demonstration when a shop coat and a pair of overalls (Figure 2), as well as large tarpaulins, were passed through a 4-in. pump without any tearing or damage whatsoever.

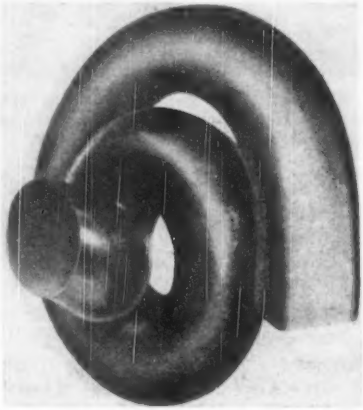


FIGURE 1.—Mock-up of impeller channel in bladeless trash pump.

FIGURE 2.—Shop coat and overalls passed by bladeless trash pump without damage or stoppage.

Actual field tests of the new pump design have been provided by long-time operation and maintenance reports of users who have not known that their replacement pumps were of the new design. That none of these units had to be dismantled, and thus release the secret of the revolutionary nature of the equipment, is further verification of the reliability of the bladeless impeller.

Additional advantages claimed for the new design include smaller motor requirement and interchangeability with present equipment.

Fair Exchange

Just planting lawns and trees is not enough in a grounds beautification program. They must also be cared for conscientiously, and just as conscientiously removed or replaced when that is indicated. How the situation has been handled at one plant is shown in Manager R. W. Frazier's 1947–48 Annual Report of the Oshkosh, Wis., Sewerage Commission as follows:

"The Lombardy poplar trees around the plant are being cut down, as they have become too large and are now considered to be a nuisance because of breaking branches, leaves, and the roots spreading in the lawn near the surface. Evergreens have been planted to replace them. A new lawn is being made in front of the building. Sludge is exchanged with the nurseries for trees and flowers."

A good point this last, as it offers a means not only of getting nursery stock with no outlay of funds, but also of disposing of excess sludge at no extra cost, even of dumping space.

Fire-Retardant Paint

A new fire-retardant and non-toxic paint now being introduced should

have a considerable appeal to those concerned with the protection and maintenance of sewage treatment works, particularly where combustible surfaces are involved. It is claimed that even the hot scorching flame of a blow torch cannot ignite a sheet of inflammable newsprint if it has been coated with the paint, which will not support combustion. Called "Flame-Seal," the coating has already been approved by Underwriters' Laboratories, and is recommended for use as an interior paint to fire retard such combustible surfaces as wood, plywood, veneer, cardboard, and various types of fibre partition boards.

The new coating is claimed to give off no toxic gases either while being applied (by brush or by spray) or when exposed to fire. No special mixing is necessary, and it may be applied during any weather conditions or season of the year, as it is not affected by humidity.

The fire-fighting property of the paint is claimed to lie in its complete physical transformation under heat to form a crust-like wall at least 8 times as thick as the original coating. It may even be possible that a little advance planning may be necessary to allow for future expansion!

Practically Utopia

At one time or another most sewage treatment plant superintendents and operators have dreamed of having at their disposal a plant that would have almost unlimited flexibility so that they could experiment to their heart's content while still performing the daily requirement.

Reading a recently published 8-page descriptive booklet about the University of Florida plant makes one realize that such dreams can come true. Not only does the plant serve an equivalent full-time contributory population of 7,000 (composed of more than 10,000 students, plus employee and faculty contributors) with adequate treatment, but it also provides research and instructional features seldom found in a plant of this size.

Treatment furnished consists of comminution, primary settling, standard-rate and high-rate filtration in parallel for comparative operation, secondary settling, chlorination, and separate sludge digestion and drying. Many pipe lines and control points are provided to give the needed flexibility for research projects studying treatment processes, equipment, and techniques. The main plant supplements the more varied facilities of a nearby pilot plant, operated exclusively as a research facility by the University's Civil Engineering Department.

Incidentally, the booklet itself is a fine example of how to acquaint plant visitors, as well as the general public, with the features of the plant, thus increasing interest and improving public relations. Among the many interesting items of the booklet is an excellent air photo of the well-kept plant, featured as the cover picture. For those who would like to see how the pamphlet is gotten up, Superintendent M. E. Dawkins says he'll be happy to send a copy to anyone interested.

Helping Hand

The helpful, cooperative spirit of sewage works superintendents and operators is attested by the following offer of the Iowa Sewage Works Association, as published in the November, 1949, issue of the *Iowa Sewage Works Digest:*

"The members of the Iowa Sewage Works Association are offering to give practical training to new operators just entering the sewage works field. The mayor or city council of cities or towns having new plants or new operators should contact the officers of the Association or their District Health Engineer, and make the necessary arrangements through one

or more plants having sufficient operating personnel to train the new men. There is no charge for this service."

It seems to us as though this could be a real in-service training program that might work to mutual advantage. Not only is it an excellent way of giving the new man some experience in the art, but it could also be a partial answer to the eternal cry for additional personnel, especially at little or no drain on the annual budget.

For Utility and Beauty

With a reminder that it is far more economical to keep a paint system in good repair than it is to wait until corrosion has destroyed a good part of the protective coating and attacked the concrete or steel underneath, a simple sewage plant painting chart especially designed for superintendents and operators is now available for easy selection of the proper paint for each plant surface and exposure condition. Besides the basic information of what paint to use where, the 4-page folder gives some valuable hints on coverages, number of coats to use, preparation of surfaces, and primers. Copies of the chart are obtainable from the Inertol Co., Inc., 480 Frelinghuysen Ave., Newark 5, N. J.

Pressure Tactics?

Advance publicity on the 1949 Annual Convention of the North Dakota Water and Sewage Works Conference certainly hinted at the promise of larger game than could be found afield when the *Official Bulletin* of the Conference said:

"Of course, Friday noon will bring the Conference to a close with a luncheon and the business session, consisting mostly of reports and the election of officers. . . . Let's have this a snappy session; hunting season opens promptly at 12:00 noon."

Well, that surely should bring it to a close—one way or another. It may even be possible to bag one's limit of officers and committeemen and then go out and get some real meat for the table!

Proceedings of Member Associations

ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION

13th Annual Meeting

Colorado Springs, Colorado, September 21–23, 1949

The 13th Annual Meeting of the Rocky Mountain Sewage Works Association was held at the Acacia Hotel, Colorado Springs, September 21–23, 1949, in conjunction with the Twenty-third Annual Meeting of the Rocky Mountain Section of the American Water Works Association.

The morning session on Sept. 21 included the following technical papers:

"Importance of Good Operation of Sewage Plants," by George Schlitt, Sanitary Engineer, Denver, Colorado;

"Stream Pollution Survey of South Platt River," by C. T. Carnahan, Public Health Engineer, United States Public Health Service, Denver, Colorado; and

"Plans and Objectives of the Federation of Sewage Works Associations," by L. O. Williams, State Sanitary Engineer, Cheyenne, Wyoming.

A business luncheon followed. The afternoon program included:

"Necessary Improvements to an Overloaded Digester," by George Hubbard, City Manager, Durango, Colorado;

"Round Table Discussion: Operator's Problems," led by M. Leonard, State Industrial Hygienist, Cheyenne, Wyoming; and

"Description of Colorado Springs Sewage Plant," by John Frederick, Plant Superintendent, Colorado Springs, Colorado.

The remainder of the day was devoted to an inspection trip to the Colorado Springs Sewage Plant.

Of the water works papers, presented on September 22 and 23, only one, "Combined Utility Operations and Records," by Harry Galligan, Utilities Auditor, Colorado Springs, Colo., was of interest to sewage works personnel.

At the Annual Business Luncheon the Association voted to increase the membership dues in accordance with the 1950 increase in Federation dues.

Officers elected for the following year were:

President: Carl M. Bennett, Colorado Springs, Colo.

Vice-President: Sam Gass, Lordsburg, N. Mex.

Secretary-Treasurer: Carroll H. Coberly, Denver, Colo.

DANA E. KEPNER,
Acting Secretary

CANADIAN INSTITUTE ON SEWAGE AND SANITATION

16th Annual Meeting

Schumacher, Canada, September 26–28, 1949

The 16th Annual Meeting of the Canadian Institute on Sewage and Sanitation was held at the McIntyre Community Building, Schumacher, Canada, September 26–28, 1949. The total attendance was 288, of whom 77 were ladies.

The opening session on September 26 was followed by a guided discussion on "Sewer Service Charges and

Methods of Financing." In the afternoon, two technical papers—"Refining of Gold Ore," by R. E. Dye, Vice-President and General Manager, Dome Mines, South Porcupine, Ont.; and "Sewer Construction in Northern Ontario," by H. E. Archibald, engineer, Teck Township, Kirkland Lake, Ont.—were presented. A discussion on "Miscellaneous Sanitary Problems," followed. Emphasis was placed on Northern activities and the addresses of the various functions all led to a better understanding of the North in general.

At the dinner that evening entertainment was under the auspices of the Canadian Sanitation Equipment Association.

On Tuesday, a technical paper, "Atmospheric Pollution and Its Control," by Morris Katz, Chairman, Canadian Section, Boundary Air Pollution Advisory Board, International Joint Commission, Ottawa, Ont., and a guided discussion, "Street Cleaning Practices," under the chairmanship of W. L. McFaul, held the interest of everyone during the morning session. During the afternoon, a sight-seeing trip to several of the local gold mines proved very interesting.

Entertainment during the evening in the form of dancing, and the "Club Room," was sponsored by the Canadian Sanitation Equipment Association.

The following papers were presented during the Sept. 28 session:

"Sewage Purification, Biofiltration," by W. B. Redfern, Consulting Engineer, Toronto, Ont., and

"Sewage Purification, Activated Sludge Process," by R. V. Anderson, Consulting Engineer, Toronto, Ont.

A discussion on "Sewer Cleaning and Maintenance" was led by C. S. Anderson.

At the business session a decision was made to raise the dues from $7 to $9 in accordance with the new Federation dues schedule for 1950.

The following officers were elected for 1949–50:

President: L. G. McNeice, Orilia, Ont.

Vice-President: D. A. R. McCannel, Regina, Sask.

Secretary-Treasurer: A. E. Berry, Toronto, Ont.

FSWA Director: Wm. Storrie, Toronto, Ont.

A. E. Berry,
Secretary-Treasurer

KENTUCKY–TENNESSEE INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

Third Annual Meeting

Lexington, Kentucky, October 31–November 2, 1949

The Joint 1949 Annual Meeting of the Kentucky-Tennessee Section, American Water Works Association, and the Kentucky-Tennessee Industrial Wastes and Sewage Works Association at Lexington, Kentucky, October 31-November 2, 1949, set a new record for registration and was called one of the most successful meetings yet held. A total of 242, including 44 ladies, was officially registered for the sessions. The program included two days of technical sessions, followed by separate inspection trips for the two Associations on the third morning.

A joint session of the two Associations, presided over by Chairman Louis Sutherland of the A.W.W.A. Section and Chairman Grant S. Bell of the Industrial Wastes and Sewage Works Association, was held on the opening day. After an opening address by Mayor Tom G. Mooney of Lexington, a paper entitled "What the A.W.W.A. Can Do for Operators and Superintendents of Small Systems" was pre-

sented by W. Victor Weir, vice president, A.W.W.A. W. H. Wisely, executive secretary of the Federation, related the "Experiences of a Sewage Plant Operator in Public Relations."

The afternoon session opened with a paper on "Investigations on Radio-Active Waste Disposal in Relation to Water and Sewage Treatment," by O. R. Placak and Roy J. Morton, Oak Ridge National Laboratory, Oak Ridge, Tenn. The session was concluded by a panel discussion on "Financing Water and Sewerage Improvements," in which W. H. Hopkin discussed the "Financier's Standpoint"; "What to Expect from Your Consulting Engineer" was presented by L. H. Clouser; and the "Municipal Viewpoint" was presented by L. S. Vance, representing Kentucky, and Arthur L. Dow, representing Tennessee municipalities.

E. E. Jacobson presided over the Tuesday morning session of the A.W.W.A. Section, at which the following papers were presented: "Occurrence of Ground Water in Kentucky and Tennessee," by geologists from both states;

"Changes in Water Rate Structures to Keep Pace with Increasing Production Costs," a panel discussion; and

"Effect of Consumer Meters on Consumption and Revenue," by R. T. Hosmon.

In the afternoon session, H. N. Jernigan presiding, the following papers were presented:

"Cathodic Protection of Tanks," by M. S. Roberts, Jr.; and

"Continuous Plan of Leak Surveys and Detection," by E. Farra.

A question and answer session on "Operating Problems of Small Plants and Systems" completed the session.

The separate session of the Industrial Wastes and Sewage Works Association on Tuesday morning, with S. L. Jones presiding, heard reports on "Current Activities in Industrial Waste Treatment," wherein E. M. Jones covered acid wastes; M. D. Sanders, meat packing wastes; and W. J. Eldridge, chemical industry wastes. M. T. Singleton followed with an interesting paper showing the unusual effect of industrial wastes on the design of the Bristol, Tenn.-Va. sewage treatment plant. Willis H. Lewis discussed the need and importance of laboratory control in sewage treatment plant operation.

Chairman Grant S. Bell presided over the afternoon session, which was opened by a discussion of "Current Activities of F.S.W.A.," by W. H. Wisely, Executive Secretary. The Federal Water Pollution Control Program was outlined by Lewis A. Young, U.S.P.H.S., Atlanta, Ga. Recent results from milk waste treatment plants were presented by Frank J. McKee and the session was concluded by a paper on "Regulation and Control of Wastes Discharged to Sanitary Sewers," by G. R. Scott.

On Wednesday morning the Water Works Section visited the Lexington water plant, the tour being concluded by a buffet luncheon. The I.W. & S.W.A. visited the Pepper distillery and waste treatment plant, and also the City of Lexington sewage treatment plant, where luncheon was served at the home of the superintendent.

The ladies entertainment committee headed by Mrs. J. K. Latham conducted a tour of Central Kentucky Horse Farms and a bridge luncheon to provide recreation for the large number of ladies in attendance. General entertainment included a cocktail hour on Monday night and a dinner dance at the Lexington Country Club on Tuesday evening.

At a joint business session preceding the inspection trips on Wednesday morning the Industrial Wastes and Sewage Works Association amended its constitution to agree with the 1950

Federation dues schedule and elected as officers for 1949–50:

Chairman: S. Leary Jones, Nashville, Tenn.

Vice-Chairman: G. R. Watkins, Lexington, Ky.

FSWA Director: M. L. Miller, Louisville, Ky.

Secretary-Treasurer: R. P. Farrell, Nashville, Tenn.

R. P. FARRELL,
Secretary-Treasurer

ARIZONA SEWAGE & WATER WORKS ASSOCIATION

1949 Fall Conference

Yuma, Arizona, November 11–13, 1949

Attendance at the 1949 Fall Conference of the Arizona Sewage and Water Works Association set a new record when 181 members and guests gathered at Yuma on November 11–13, 1949. Technical sessions and entertainment features were well attended and the meeting was hailed as one of the most outstanding yet held.

President Anton Frederickson presided over the opening session, which got under way with a Johns-Manville film, "Underground Arteries." The paper "Centrifugal Pumps: Application and New Developments" presented by H. A. Mylander, De Laval Steam Turbine Company, Los Angeles, created considerable interest and won the award for the best paper of the conference. The remainder of the morning was devoted to a discussion on protection of water distribution mains.

Arizona State Supreme Court Judge Evo DeConcini gave an interesting discussion of "Water Rates" at the Friday luncheon, comparing the various rates in force in the state, ranging from a high of $3.00 per 1,000 gal. in one northern Arizona community where water is hauled from a considerable distance, to a low 5¢ per 1,000 gal. in Yuma. Judge DeConcini discussed the various factors governing the establishment of water rates and cited methods of figuring depreciation.

The afternoon technical session was opened with a report by Russell Ludwig, Pasadena consulting engineer, of recent research in Los Angeles County dealing with the reclamation of sewage and industrial wastes. Charles E. Trygg, sanitary engineer, Arizona State Department of Health, presented an illustrated discussion of "Biology of Sewage Treatment." This was followed by a panel discussion on methods of financing water and sewer main extensions.

Byrl D. Phelps, San Diego consulting engineer, presided over the festivities of the Friday banquet. The featured speaker was J. J. Hinman, Jr., past president of A.W.W.A., who gave an entertaining and humorous slide-illustrated talk on the weighty subject of "Foulk's Law as Applied to Post-Curricular Achievement."

The Saturday morning session was opened with an interesting film presented by Chicago Bridge and Iron Company, dealing with the erection of an elevated water sphere. W. W. Williams, consulting engineer, Phoenix, described the rehabilitation of the Yuma water works, where recent additions to the treatment plant have enabled the utility to increase production of filtered water from a maximum of approximately 5 m.g.d. in 1947 to 10 m.g.d. in 1949. The morning session concluded with a panel discussion dealing with the problem of consumer complaints.

At the Saturday luncheon, A.W.W.A. Director A. W. Miller reported the activities of A.W.W.A. during 1949. At the business session on Saturday, John A. Carollo reported for the Committee on Certification and recommended that a certification and training program

be initiated in 1950. The training program will be developed under the guidance of the Arizona State Department of Health.

The Operators' Roundup, a popular feature of the Arizona meetings, was held Saturday afternoon under the guidance of John Hoover, superintendent of utilities, Mesa. The Roundup is a closed session for operators only and is devoted to informal discussions of common problems. At the parallel technical session, Lester M. Louden, chief chemist, Los Angeles Department of Water and Power, presented a paper on "Chemical Limits in Drinking Water Standards." Richard F. Poston, Officer in Charge, Western Gulf Colorado Basin Office (U. S. P. H. S.), Dallas, Tex., discussed "Water Pollution Control Under Public Law 845" and pointed out the aims of the new federal program. Leland Glidden, Paulden, Ariz., described the Ranney collector system in his paper "Naturally Filtered Water Through Induced Infiltration From Surface Water Bodies." J. M. Lackey, district engineer, The Asphalt Institute, Los Angeles, discussed the "Use of Asphalt in Hydraulic Works."

The Saturday evening banquet, traditionally informal in nature, was presided over by Toastmaster A. W. Miller. Entertainment for the evening was provided by the staff of the local radio station, KYUM, under the direction of its manager, Ray Smucker. The theme of the hilarious variety show presented on the "broadcast" was "Experimental Instrumentation of Public Relations" and revealed how water pressure variation is a better guide to radio listener reaction than the famed "Hooperating." During the rites of the Select Society of Sanitary Sludge Shovelers, W. Victor Weir, O. V. Cooper, Ray Smucker, Jack J. Hinman, Jr., and M. P. Goudy were elevated to membership in the exclusive Society. Following the dinner, members and guests attended a dance where members of the Water and Sewage Works Manufacturers Association were hosts.

A tour of the new additions to the Yuma water treatment plant, and an inspection of the Morales Dam in Mexico on Sunday morning concluded the Conference.

MRS. HELEN ROTTHAUS,
Secretary

JOHN H. GARNER RETIRES

John H. Garner, chief inspector of the West Riding of Yorkshire Rivers Board, retired in October, 1949, after 20 years in his present position and more than 42 years in the Board's service. Mr. Garner has for many years enjoyed an international reputation in matters of treatment of sewage and industrial wastes as they pertain to stream pollution abatement and prevention.

During the past 30 years, Mr. Garner has taken an active part in the work of the Association of Managers of Sewage Disposal Works, which since 1932 has been a member association of the Federation under the name of the Institute of Sewage Purification. He was President of the Institute in 1935 and 1936, and has already been invited to accept the honor of again being President in 1951, when the Institute celebrates its Jubilee.

Mr. Garner served the Institute as a Federation Director from 1933 to 1942 and from 1945 to 1947, receiving the Kenneth Allen Award in 1946 for his services to the Institute. It was mostly through his efforts as Contact Member of the Institute, a position he has held since 1932, that the Institute in 1947 won the Federation prize for greatest numerical increase in membership.

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Texas Water and Sewage Works Association	College Station, Tex.	Mar. 12–16, 1950
Louisiana Conference on Water Supply and Sewerage	Louisiana State University, Baton Rouge, La.	Mar. 15–17, 1950
New Jersey Sewage Works Association	Stacy-Trent Hotel, Trenton, N. J.	Mar. 22–24, 1950
Virginia Industrial Wastes and Sewage Works Association	Geo. Washington Hotel, Winchester, Va.	Mar. 30–31, 1950
Arizona Sewage and Water Works Association	Safford, Ariz.	Mar. 31–Apr. 2, 1950
Arkansas Water and Sewage Conference	Robinson Memorial Auditorium, Little Rock, Ark.	Apr. 17–19, 1950
Kansas Sewage Works Association	Lamar Hotel, Salina, Kans.	Apr. 20–21, 1950
Montana Sewage Works Association	Florence Hotel, Missoula, Mont.	Apr. 20, 1950
California Sewage Works Association	Lafayette Hotel, Long Beach, Calif.	May 3–6, 1950
Pacific Northwest Sewage Works Association	Winthrop Hotel, Tacoma, Wash.	May 10, 1950
Michigan Sewage Works Association	Park Place Hotel, Traverse City, Mich.	May 22–24, 1950
Alabama Water and Sewage Association	Alabama Polytechnic Institute, Auburn, Ala.	June 6–8, 1950
Central States Sewage Works Association	Indianapolis, Ind.	June 9–10, 1950
New York Sewage and Industrial Wastes Association (Spring Meeting)	Hotel Jamestown, Jamestown, N. Y.	June 12–13, 1950
Ohio Sewage and Industrial Wastes Treatment Conference	Gibson Hotel, Cincinnati, Ohio	June 28–30, 1950
Pennsylvania Sewage and Industrial Wastes Association	Pennsylvania State College, State College, Pa.	Aug. 23–25, 1950
Iowa Sewage Works Association	Hotel Blackhawk, Davenport, Ia.	Sept. 19–21, 1950
Rocky Mountain Sewage Works Association	La Fonda Hotel, Santa Fe, N. Mex.	Sept. 27–29, 1950
Missouri Water and Sewerage Conference	Sheraton Hotel, St. Louis, Mo.	Oct. 1–3, 1950
Federation of Sewage Works Associations	**Hotel Statler, Washington, D. C.**	**Oct. 9–12, 1950**
North Carolina Sewage Works Association	Washington-Duke Hotel, Durham, N. C.	Nov. 13–15, 1950

Reviews and Abstracts*

The Influence of Nickel on the Purification of Sewage by the Activated Sludge Process. By Harold Hill. *Jour. and Proc.*, The Institute of Sewage Purification (England), Part 1, p. 161 (1947).

Experiments were carried on to study the effect of nickel on the activated sludge process. Aeration vessels of 2-l. capacity and fitted with small diffusers were used. Activated sludge from a Simplex aeration plant was mixed with domestic sewage, in batches, until practically identical effluents were obtained. Three fillings a day were made, with 6-hr. aeration periods and 2-hr. settling periods for each batch. When identical effluents were produced a nickel solution was added to one set of settled sewage samples prior to aeration. Four series of tests were made using 1, 3, 6, and 10 p.p.m. nickel as nickel sulfate.

Results indicated that nickel salts exerted a toxic effect on activated sludge, and that concentrations between 1 and 2 p.p.m. inhibit nitrification but do not apparently affect clarification. Concentrations of 10 p.p.m. had a pronounced toxic effect.

It is to be noted that these results apply to conditions of continuous dosing.

T. L. Herrick

Some Experiments on Rapid Sand Filtration of Sewage Works Effluents Without Coagulants. By P. B. B. Vosloo. *Jour. and Proc.*, The Institute of Sewage Purification (England), Part 1, p. 204 (1947).

At one time it was contemplated selling the effluent from the Ancor sewage works of the Town Council of Springs (South Africa) to an industrial concern. One requirement was that the effluent be sand filtered. At the McComb works, humus tank effluent is filtered through slow sand filters at an average rate of 3 gal. (Imp.) per sq. ft. per hour. The actual yield is but 1 gal. per sq. ft. per hour, as about two-thirds of the time is required for drying and cleaning the surface. Because of the high cost of slow sand beds for the Ancor works it was decided to investigate pressure filtration.

A filter was obtained for experimental purposes which was 2 ft. in diameter and 4½ ft. high. The filtering medium, supported on a false floor, consisted of 3½ in. of 0.5- to 0.25-in. pebbles, 3½ in. of 0.25- to 0.10-in. pebbles, 5 in. of 10 to 20 mesh sand, and 2 ft. of 20 to 30 mesh sand. The unit was closed by a domed cover fitted with a shaft carrying a rake for loosening the sand surface when backwashing.

One test run of 7 hr., during which samples were taken every 10 min., indicated a reduction in suspended matter from 24.3 p.p.m. to 0.7 p.p.m. at a rate of 200 gal. per sq. ft. per hour. In another test, the results showed complete reduction of 21.7 p.p.m.

A tentative design for the Ancor works contemplates an average filtering rate of 120 gal. per sq. ft. per hour, with a maximum of 200. The wash water would amount to about 5 per cent of the total flow. Provision is made for a maximum head of 10 ft. The estimated cost is approximately one-half that estimated for slow sand filters.

T. L. Herrick

The Seattle Sewage Treatment Problem. Pollution Control Commission, State of Washington. 13 pp. (Nov., 1948).

In this report, the Commission comments on a report by Wolman. The 1945 pollution control law of the State of Washington is cited as requiring the proper treatment of all sanitary sewage,

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

and the pouring of raw sewage into the nearest water course is held to be a violation of that law. The Commission requires that "the minimum acceptable degree of treatment for the sewage and industrial wastes of the City of Seattle will be primary treatment."

The high capacity of Puget Sound assumed by Wolman is criticized severely. The Commission report says the facts, with respect to the biochemical condition of the Sound, are that the swimming beaches in the area immediately adjacent to the City have been seriously polluted since 1941 and unsatisfactory for bathing. The laxity of the City in its attention to the sewerage problem is reviewed.

The Commission recognizes the need for deep water outfalls, but believes that for effectiveness they must be preceded by partial primary treatment. Among the major points emphasized is the need for proper treatment to protect the local situations, particularly the condition of pollution existing at each of the city outfalls, which affect adjacent shorelines and, in some cases, the deeper waters in Puget Sound distant two miles or more.

Wolman's suggested criteria for outdoor saline waters, which must necessarily be the standards of the Washington Department of Health and the Pollution Control Commission, are based on a *B. coli* count of 2,400 as acceptable, whereas the Washington standard is 50.

The improvement of the North Trunk sewer is criticized, because the Commission doubts the effectiveness of comminution alone.

The Commission urges that minor sewers be picked up in a program of interception and treatment, and agrees that the policy of separate sanitary and storm-water systems should be carried out, as well as development of a master plan for sewer extension and controlled sewage disposal.

LANGDON PEARSE

Pollution of the Androscoggin River by Industrial Wastes and Control Measures Thereof. BY E. SHERMAN CHASE. *Journal Boston Society of Civil Engineers*, **36**, 357 (July, 1949).

A detailed description is given of the seriously polluted condition of the Androscoggin River in Maine, draining a watershed of 3,470 sq. mi., with a monthly flow at Rumford averaging 2,212 c.f.s. to 8,552 c.f.s. in the years 1928 to 1941, inclusive. The lower flows occurred in the period from August to October and averaged 2,446 c.f.s. The natural flow is regulated by a storage of 225,000 m.g. above Rumford and 28,000 m.g. below. The sewered population totals 108,700, mostly above Rumford. The equivalent population of the industries (97 per cent pulp and paper mills; of which 87 per cent is from sulfite wastes) totaled 2,411,500 in 1941. Large amounts of hydrogen sulfide were generated in the vicinity of certain mill towns and created a public nuisance.

The author holds that a reasonable criterion for pollution control is the maintenance of dissolved oxygen in the river water at all times.

Reaeration was estimated at 1,000 lb. of D.O. per mile of river, after correcting for the depleting effects of sludge deposits and the benefits of tributary streams. The net amount of oxygen obtained by reaeration was estimated at 135,000 lb. per day. In 1941, the average daily demand for oxygen by months ranged from 150,400 to 617,800 lb. In 1941, from June to October, there were oxygen deficits ranging from 128,900 to 405,900 lb. In other months of the year, the available oxygen equalled or exceeded the demand.

Four general relief measures were considered; sewage treatment, industrial waste treatment, storage of industrial wastes, and storage of dilution water. Sewage treatment for the municipalities required expenditures out of proportion to the benefits to be derived. The use of the soda process by the Oxford Company is helpful, with recovery of fibre by save-alls. The lagoon capacity required for storage totaled 255.5 m.g. Estimates indicated that storage in the period of June to October, inclusive, could be let down in the other months of the year. Stored digester liquors lose a substantial proportion of their oxygen demand over several weeks.

The river is well regulated for power purposes, and the let-down for power coincides closely with the need for dilution. Consequently, the construction of storage for diluting water was not advocated.

As the mills failed to undertake the remedial measures recommended, the Attorney General of Maine began legal proceedings in May, 1942, to secure relief.

In view of war conditions, a stipulation was entered into for an experimental lagoon at the Oxford Company; weekly sampling and analyses of the river water during May to September, 1943, inclusive; and restriction of discharge of sulfite wastes at certain times. The lagoon tests indicated that a local nuisance did not result.

As the foregoing measures did not provide adequate relief, a 1944 decree of the Court continued sampling of the river and restriction of sulfite waste liquor discharge.

In 1947, a modified decree continued the sampling schedule and required a 22-m.g. lagoon at the International Paper Co. for storing waste sulfite liquor. Supervised sampling and regulated operation of the lagoon was initiated to maintain 4 p.p.m. of D.O. in the river at a certain location. These provisions were beneficial but not adequate. In December, 1948, a new decree appointed an administrator, provided for weekly sampling and analyses of the river from May 1 to October 15 each year, specified criteria for control of the industrial waste let-down in relation to river flow, and provided for the use of at least 1,000 tons of soluble nitrate in the river at critical periods when ordered by the administrator. The production of sulfite pulp was to be allocated by the mills among themselves.

In 1948, a low summer flow indicated that the measures taken afforded substantial but not complete relief. The measures were:

1. Reduction of sulfite liquor from Brown Co. to about one-third, when odor conditions were worst.

2. Storage in the open lagoon and elsewhere of most of the sulfite liquor from the International Paper Co.

3. Addition of sodium nitrate near the beginning of the pool just above Lewiston.

The significant aspects of the Androscoggin River pollution problems are:

1. The tremendous pollutional effect of the sulfite waste liquors as compared with other sources of pollution.

2. The correlation of odor conditions during the summer in the Lewiston-Auburn area, with the concentration of sulfite liquor in the river.

3. The apparent benefit in odor control by the addition of sodium nitrate to the river.

4. The recognition by the legal authorities of the importance of the industries in the Androscoggin valley to the economy of the valley and the State.

5. The natural reluctance of the industries to undertake remedial measures without some assurance of their effectiveness, with a minimum expenditure.

6. The slow but steady progress in alleviating the nuisance, with a minimum of drastic action by the Attorney General and the Court.

7. The unique assignment to a non-governmental individual of the task of supervising the river condition and policing his own clients.

Various tables and graphs are included.

LANGDON PEARSE

Report of the Rivers Department, City of Manchester, England, for Two Years Ending March 31, 1948. 74 pp.

This report covers the operation of the sewage works at Manchester, England. The bulk of the sewage from 863,000 population is treated at the Davyhulme works and a small portion (47,000 population) at the Withington works. Experimental work on dewatering sludge is also described, and the control of trade effluents.

In the periods 1946–1947 and 1947–1948, the daily volume of sewage at Davyhulme was 59.69 Imp. (71.6 U.S.) m.g.d. and 56.79 Imp. (68.1 U.S.) m.g.d., respectively, or 75 Imp. (90 U.S.) g.p.c.d. and 70 Imp. (84 U.S.) g.p.c.d. The sewage contained 150 and 145 p.p.m. of suspended matter and 229 and 237 p.p.m. B.O.D. for the respective periods. All the sewage is settled, the effluent being divided among contact beds and activated sludge plants, in part by diffused air and in part by bio-aeration and by a Simplex plant. In the diffused air plant, diffusers of the dome type are under trial. The air consumption is 0.72 cu. ft. per Imp. gal. (0.6 cu. ft. per U.S. gal.). In the diffused air plant the periods of aeration varied from 8.1 to 8.6 hours. In 1946–1947, the effluents contained from 14.3 to 15.7 p.p.m. of B.O.D., and from 19 to 21 p.p.m. of suspended solids. The bio-aeration plant (16.6 hr. detention) and the Simplex plant (12.3 hr. detention) produced effluents of about the same B.O.D. and suspended solids strength.

In 1947–1948, the effluents contained

from 16.9 to 19.9 p.p.m. of B.O.D., and 21 to 22 p.p.m. suspended solids for the diffused air, with periods from 9.0 to 10.1 hours. The bio-aeration and Simplex effluents were about the same as in the earlier period. The entire plant effluent averaged 49.9 and 44.2 p.p.m. B.O.D. and 33 and 29 p.p.m. suspended solids for the two periods, and 2 p.p.m. of nitric nitrogen. Sludge is pumped to storage tanks and mostly sent to sea (232,240 and 256,400 tons in the respective periods). A new oil-fired boat has been acquired since World War II ended. Surplus activated sludge is mostly disposed of at sea with the primary sludge. A small amount of sludge is digested with heat as an experiment for 12.6 days, or lagooned.

The Withington works handle about 2 Imp. (2.4 U.S.) m.g.d. with an average flow of 43 Imp. (51.6 U.S.) g.p.c.d. All the sewage is settled; part is given activated sludge treatment, and part goes to contact beds. The sewage contains about 190 p.p.m. B.O.D. and 68 p.p.m. suspended solids. The activated sludge effluent contains 13.2 p.p.m. B.O.D. and 11 p.p.m. suspended solids, and 2 p.p.m. nitric nitrogen. The plant effluent averaged 16 p.p.m. B.O.D. and 13 p.p.m. suspended solids. The wet sludge is mostly pumped to sludge trenches.

Appendix II gives detailed cost figures.

Appendix III describes semi-micro determination of nitrogen in sewage sludges.

Appendix IV (C. Jepson and L. Klein) describes heat treatment of excess activated sludges at temperatures from 60° to 90° C. for 5 to 35 min., and tests on heat-pressure treatment, using pressures from 75 to 150 p.s.i. The conclusion is that by heat-treatment at high pressures, the proportion of solid content is rapidly increased. The solid matter content depends largely on that of the original sludge, but is also influenced by the steam pressure applied and the time of application. The effect of the initial dry solids content is shown in the following table, in which the results are arranged in increasing order of the initial solid content:

Dry Solids Content of Sludge (%)

Initial	Treated
0.80	2.49
2.01	4.62
2.31	4.99
2.59	5.85
4.84	7.80

The heat-treated sludge settles readily, separation usually being complete in less than 2 hr. The separated liquor is foul, but unless the sludge treated is very stale the smell is not very objectionable. The liquor may contain up to 36 per cent of the original solids and 59 per cent of the original nitrogen content in solution.

The densified sludge filters readily and can be dewatered rapidly on drainage beds or by mechanical means. Heat-pressure treatment has an inhibitory effect on the subsequent digestion of sludge, which is more marked when the material treated is a mixture of primary and surplus activated sludge.

Appendix V describes experiments with a semi-scale Dorr Oliver vacuum filter using chlorinated copperas as a coagulant (C. Jepson and G. Greene). With activated sludge a cake of 83.5 to 89.8 per cent moisture was obtained, with an output of 0.74 lb. dry solids per sq. ft. per hr. and an average chlorinated copperas demand of 19.1 per cent. Aeration prior to filtration had little influence on output, but reduced the amount of chlorinated copperas required. Filtration of elutriated digested sludge produced a cake with moisture content of 72 to 75.9 per cent, with an output of 1.35 to 1.72 lb. dry solids per sq. ft. per hr. and an average chlorinated copperas demand of 13 per cent.

Compared with ferric chloride, chlorinated copperas has two main disadvantages —more is required to obtain the same result, and the rate of filtration is slower. However, at Manchester, the authors conclude that chlorinated copperas is cheaper than ferric chloride and appears to be a practical and economic substitute.

LANGDON PEARSE

Disposal of Softening Plant Wastes—Committee Report. *J. Amer. Water Wks. Assn.*, 41, 9, 819 (Sept., 1949).

Lime and Lime-Soda Sludge Disposal. BY A. P. BLACK.

This report summarizes the work accomplished by American Water Works Association Committee W-8 on Disposal of Wastes from Water Purification and Softening Plants. An original progress report was made at the San Francisco Conference in 1947 (See abstract, THIS JOURNAL, 20, 4, 779 (July, 1948).

Disposal of lime or lime-soda softening

plant sludge is rapidly assuming greater importance because this country is rapidly becoming "soft water conscious," the country is also becoming "pollution conscious," and the increase in the population of urban regions has restricted the availability of land in such areas for disposal of sludges by ponding or lagooning. Data are given on chemical composition, particle size, quantity, physical character, and volume of sludge.

In the past, sludge disposal has been almost exclusively accomplished by lagooning or dilution in a stream or other body of water. Four additional methods that now offer attractive possibilities are utilization as a precipitant in primary sewage treatment if the first plants using this process are successful; dewatering, drying, and pulverizing, and disposing of the dried product for a variety of industrial uses; dewatering and calcining in small stationary kilns (two types); and recalcining in rotary kilns for the larger installations. Progress on all four methods will be watched with interest.

Brine Disposal from Cation-Exchange Softeners. By Paul D. Haney.

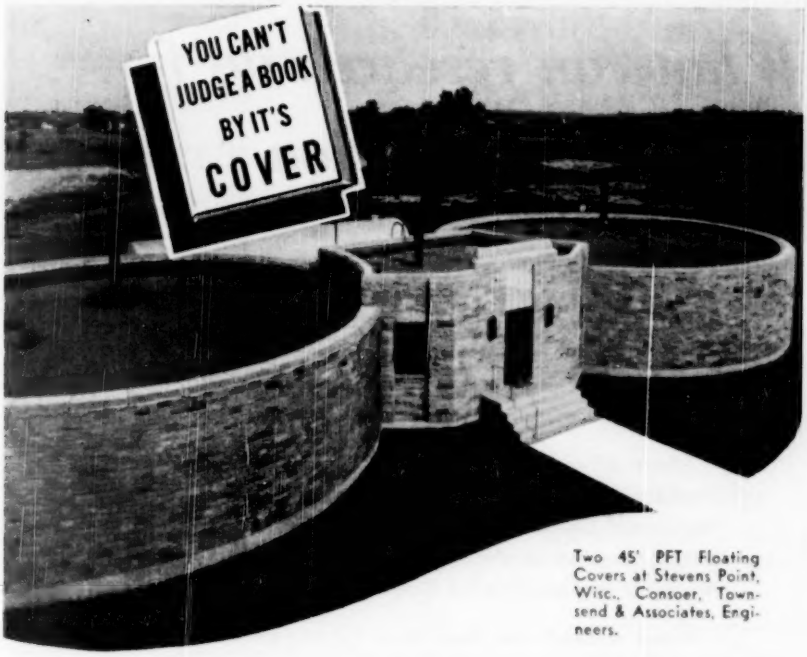
This material covers wastes from sodium zeolite water softening plants and consists of wash water containing the waste products of the regeneration cycle, plus unused salt. These waste products are composed principally of the chlorides of calcium and magnesium, together with small amounts of various compounds of iron and manganese. A complete brine analysis is given of a composite sample of spent material discharged from one large zeolite plant.

Deleterious effects are produced on water supplies by the increase in chloride, sodium, calcium, magnesium, and solids concentrations. Such damage is irreparable as far as any treatment method generally available for use by a public water supply is concerned. Effect of brine on sewage treatment processes, on fish life, and on animals is also considered. Certain fish can tolerate 5,000 to 10,000 p.p.m. of sodium chloride for short periods, but calcium and magnesium appear to be more toxic. A total salt content of 15,000 p.p.m. is considered to be the upper limit for stock water. A number of operating problems on brine disposal are cited.

Spent brine disposal may be classified under the following four methods: evaporation ponds, uncontrolled dilution, controlled dilution, and brine disposal wells. Of these methods, controlled dilution appears to offer the most generally applicable means of handling the wastes from zeolite softening plants, but this method will be unsatisfactory unless ample dilution water is available at the time of brine release and unless releases are carefully controlled. Uncontrolled dilution and evaporation methods usually will not be a practicable solution to the problem. However, brine disposal wells may offer an acceptable answer as a disposal means if the volume of wastes is large and the subsurface geology is suitable for underground disposal.

A check list is given for the planning of brine disposal from cation-exchange softening plants.

Robert P. Lowe



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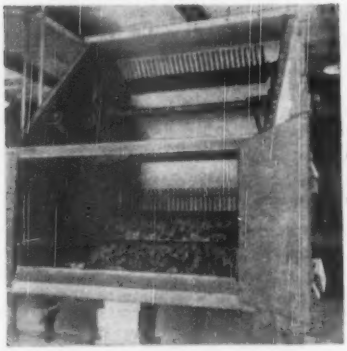

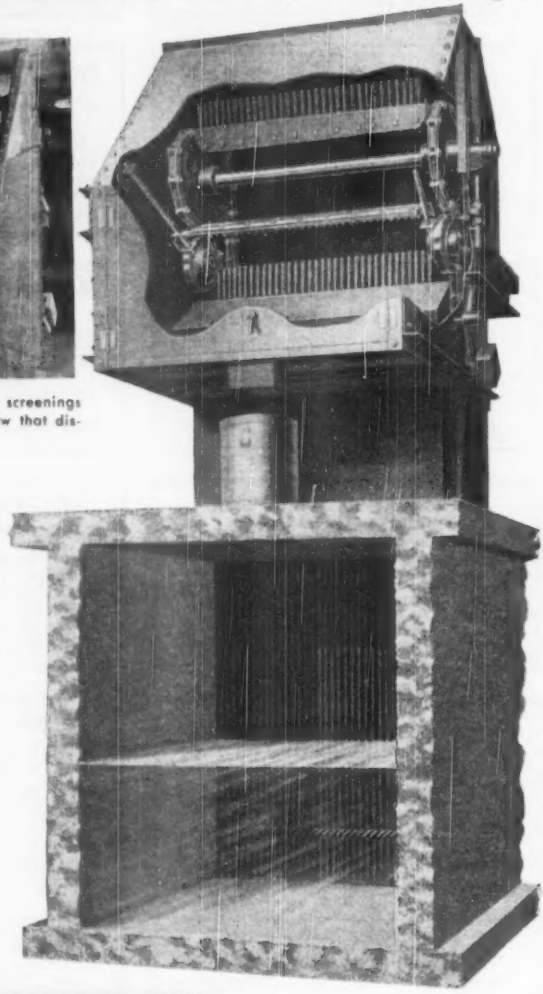

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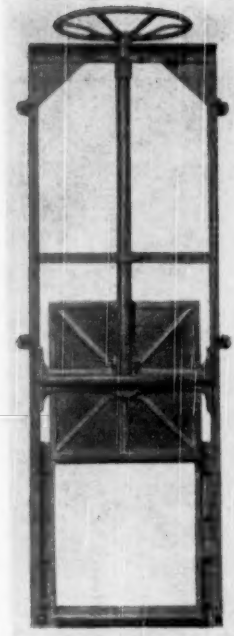

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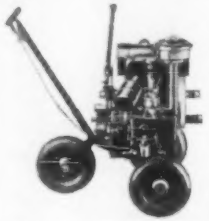

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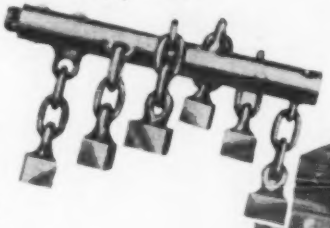

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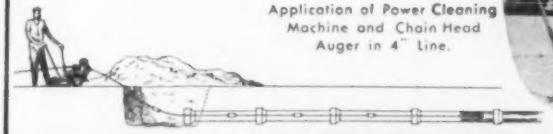

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